DECEMBER 1955

THE WELDING JOURNAL

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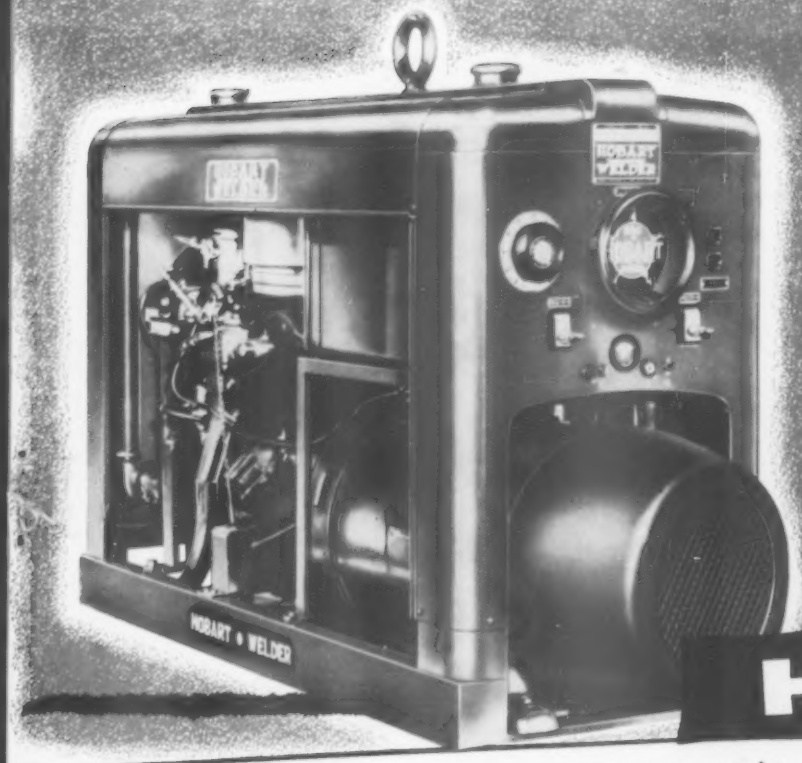

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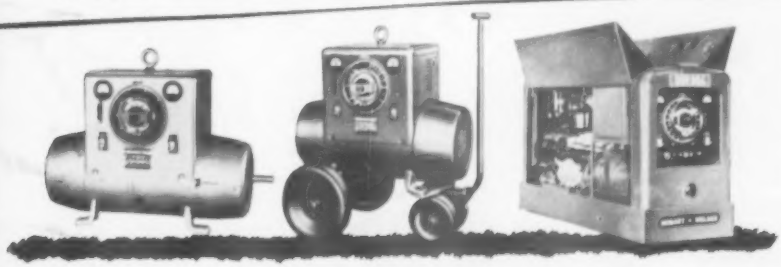

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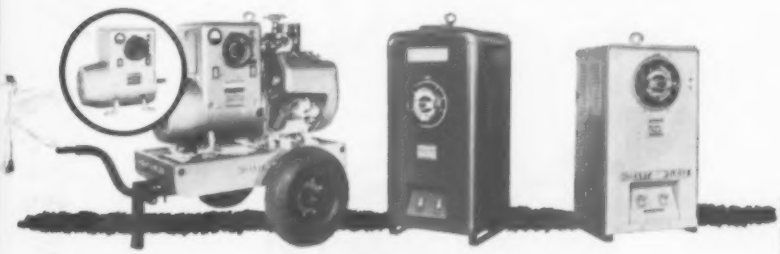

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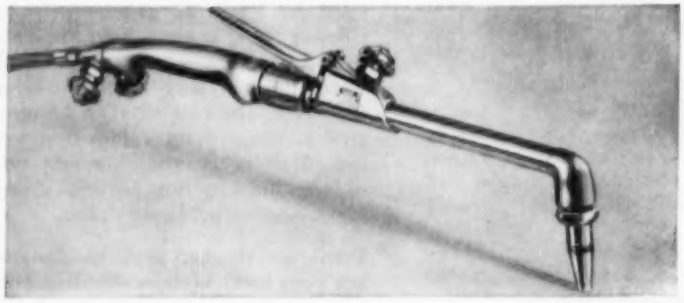

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THE WELDING JOURNAL

VOLUME 34 • NUMBER 12 • DECEMBER 1955

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But there was a weldor at the plant who knew what Ni-Rod "55"* electrodes could do and how to use them.

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This repair is typical of the difficult cast iron welding jobs that are being done every day with Ni-Rod "55" and its companion electrode, Ni-Rod*. To get a better idea of the repairs you can make with these electrodes, write for our folder, "Repair Cast Iron Parts Quickly and Easily."

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Ni-Rod "55" electrode had just been introduced 3½ years ago. Today most weldors depend on it for repairing cast iron.

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This weld was made 3½ years ago with Ni-Rod "55" electrodes. Read how the weldor made $500 worth of repairs and saved six weeks down time, too.

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INTERNATIONAL WELDING STANDARDS

It has been my recent privilege to listen to a very stimulating report by the American representatives to OEEC Mission 250 on European Welding Operations and to take part in discussions with the authors. This report, presented at the September meeting of the American Council of the International Institute of Welding and published in the October issue of THE WELDING JOURNAL, is worthy of the study and thought of the entire industry.

It should be remembered that large quantities of welding apparatus moved across the ocean from this country in the early postwar years and that no small part of the rapid development of the welding industries in Europe is based on that apparatus.

Let us not make the mistake of imagining that the science and practice of welding will inevitably center around what we do in the United States. Abroad, through the instrumentality of the International Institute of Welding, a sincere effort is being made to pool knowledge and experience. It is intended thereby to obtain international acceptance of standards for the industry which will facilitate the flow of welding apparatus, materials and welded products back and forth across national borders.

Active participation in this effort from our side of the water may well prove vital to our own industry if we are at all interested in the export and import of apparatus, materials and welded products.

The science and practice of welding are still in a stage of development where some degree of international standardization should not be impossible of attainment. Consider the benefits we would all have been enjoying had it been feasible to tackle internationally the problems of units of measurement and the standardization of screw threads at a correspondingly early stage.

Walter L. Green

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The mark made by a TEMPILSTIK° may gradually change in color as heating progresses. The change in color, or in color intensity, is never to be interpreted as a temperature indication. The TEMPILSTIK° mark melts when its temperature rating is reached and only this change from the dry to the liquid condition is the significant temperature signal.

In some applications this simple method may not suffice because evaporation of the TEMPILSTIK° mark on prolonged heating, or its gradual absorption by the surface at high temperatures, may leave too little residual substance for unambiguous observation. In such cases stroking or touching the work-piece with the TEMPILSTIK° at regular intervals during the heating process is recommended. The TEMPILSTIK° will leave a dry mark at temperatures below its rating and a liquid streak when its temperature rating has been reached or exceeded. If the workpiece is not accessible for applying a TEMPILSTIK° during the heating process, then TEMPILAQ°, or possibly TEMPIL° PELLETS, should be used instead.

TEMPILSTIKS° will usually glide over unheated polished surfaces (like glass, polished stainless steel, etc.) without leaving an appreciable mark. Therefore, in applications that involve smooth or polished surfaces TEMPILSTIKS° should be used by touching or stroking the workpiece periodically during the heating process, as previously described, because a liquid streak will be made on contact as soon as the specified temperature is reached. Where it is necessary to mark a smooth work piece surface prior to heating, TEMPILAQ° should be used.

A hot radiating surface will appear relatively dark under intense illumination from an external source, and this fact can be utilized to improve recognition of the temperature signal against a red-hot background. The use of TEMPIL° PELLETS or TEMPILAQ° instead of TEMPILSTIKS° will further improve visibility under these conditions.

On rapidly moving objects, like magnesium or aluminum sheet during spinning operations, it is impossible to see whether the applied TEMPILSTIK° leaves a dry or melted mark. However, with a little experience operators quickly learn to sense the smooth gliding of a TEMPILSTIK° over a surface which is hot enough to melt it on contact, as contrasted to the frictional drag on a cooler surface. If the top of the TEMPILSTIK° is brought in contact with the moving metal surface for a brief moment at a time, and with light pressure only, the heat contribution of friction is trivial enough to be ignored.

The above described "sensing technique" may also be employed on hot radiating surfaces where the bright background makes it difficult to distinguish whether or not the TEMPILSTIK° mark had melted.

An appropriate series of TEMPILSTIK° marks, applied to the workpiece or surface under investigation before heating begins, will provide a record of the maximum temperature attained during a process or operation. Subsequent examination will show that all TEMPILSTIK° marks up to a certain temperature rating had melted, while those of a higher rating had not. The maximum attained temperature must consequently lie somewhere in the interval between the highest melted and the lowest unmelted TEMPILSTIK° rating.

The temperature distribution and isothermal boundaries of surfaces such as furnace walls, melting ladles, cement kilns, etc., can be established by using an appropriately chosen series of TEMPILSTIKS° to draw a pattern of lines (parallel, concentric, radial, etc.) on the area under investigation. The heat conduction along a surface can be effectively studied by the progressive melting of suitably chosen TEMPILSTIK° lines. Caution must be exercised not to permit the mark made with one TEMPILSTIK° rating to cross or overlap the mark of a dissimilar TEMPILSTIK°, as such a mixing of different TEMPILSTIK° marks would destroy their accuracy.

TEMPIL° products will give good results in induction heating and in ionized air, as well as in the presence of static electricity about electrical equipment, where electrical means of measuring temperatures often function erratically.

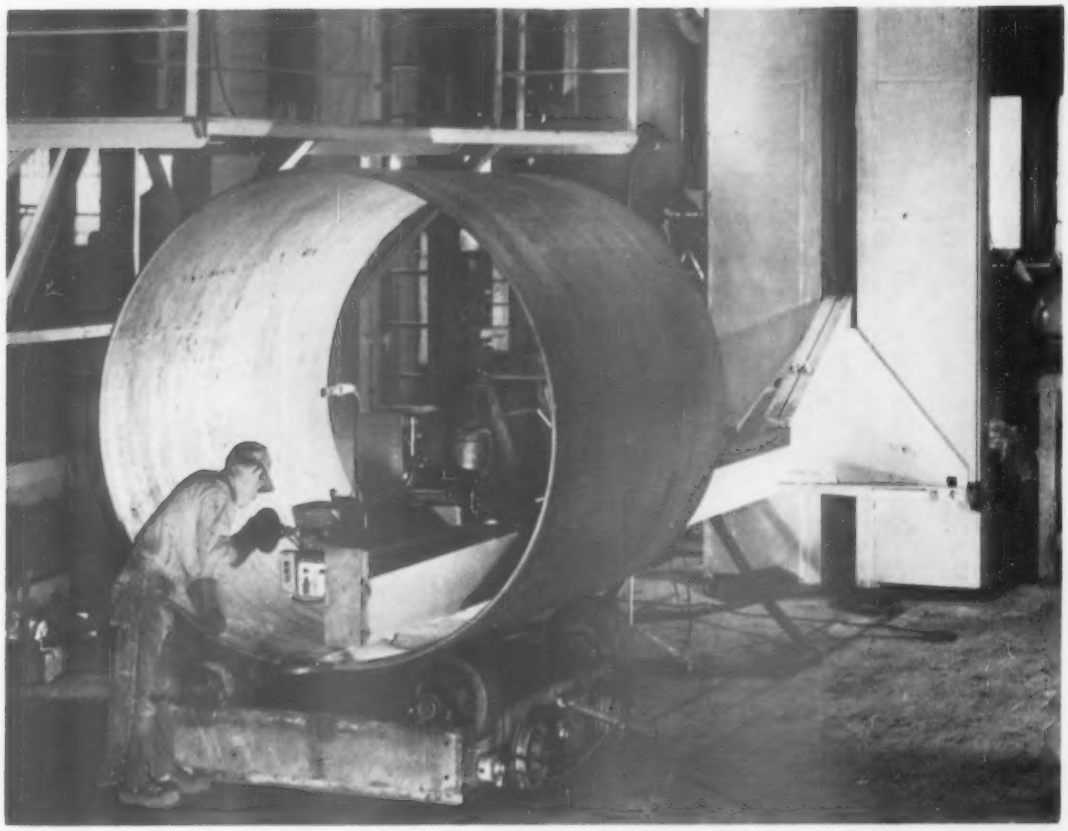

Fig. 1 Submerged-arc welding equipment mounted on adjustable boom with controls and instruments

HOW TO WELD HIGH-PRESSURE VESSELS WITH AUTOMATICS

With the right fixtures, controls and work preparation, automatic submerged arc stations can handle an almost endless variety of jobs

BY WILMER W. WEBER

Introduction

A surprising range of welding jobs are performed at our plant by submerged arc automatics. Typically, quality is higher and costs far lower than manual welds.

All-welded equipment includes high-pressure reactors, vats, tanks, columns and a variety of custom-built processing machinery. Both internal and external welds are performed automatically on either circumferential or longitudinal seams.

Work dimensions are equally varied. Vessels range in diameter from 3 to 13 ft and may be up to 50 ft long. Plate thicknesses vary from $^1/_4$ to $1^3/_4$ in., widths from 36 to 140 in. and lengths from 7 to 45 ft.

The most frequently used material is ASTM Grade 285B flange quality steel, but we also handle a dozen or more alloys on our automatics regularly. Despite these variations, weld quality has to be tops because most of the vessels are glassed after welding is completed to withstand corrosion of chemicals. Flawless

Wilmer W. Weber is Welding Engineer, The Pfaudler Co., Rochester, N. Y.

Presented at 1955 AWS National Fall Meeting in Philadelphia, Pa., October 17–21.

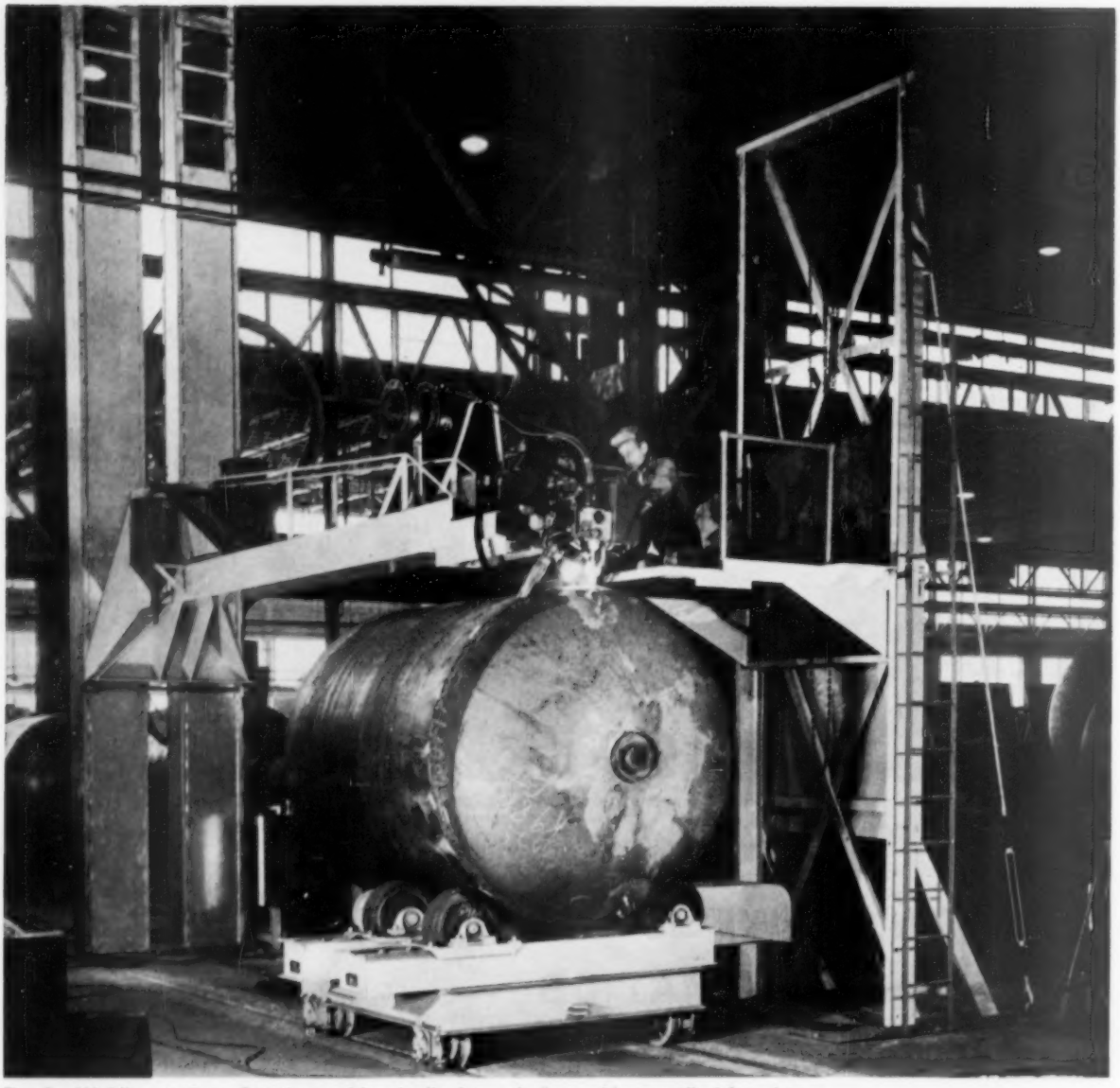

Fig. 2 Welding station. Rotation and longitudinal travel of vessel is controlled from boom

welds are a prime requisite for an impervious glass or alloy surface and for proper performance of the vessel. Furthermore, internal pressures range from full vacuum up to 225 psi.

Company engineers have been surprised at the variety of jobs that can best be handled by automatics. Problems? Definitely. And we surely don't have all the answers. But since we started using this process 14 years ago, we've uncovered a few which may be helpful to the reader.

The key points to consider for good results with submerged arc welding are selection of the right equipment, joint design, preparation of edges, welding procedure specifications and quality control. As a basis for our consideration of these factors, let's review how submerged-arc welding equipment operates.

Explanation of Process

The submerged-arc welding process, or hidden arc process as it is sometimes called, was relatively unknown 14 years ago. It was during the Second World War that speed-up in our welding processes was started to expedite production. This process really came into its own at that time and today is used widely in industry.

The submerged-arc welding process is just what its name implies. The arc is completely covered by a blanket of granulated mineral material called flux, and cannot be seen. As the arc between the electrode and the workpiece generates heat, molten metal is deposited from the electrode under the blanket of flux. A portion of this flux becomes molten and solidifies on the surface of the weld metal. In this manner the de-

posited weld metal is completely protected from the atmosphere and is practically hydrogen free. Because the arc is completely hidden, the operator needs no helmet or glasses to protect him from arc flashes or spatter. The process is also practically smoke free and the presence of obnoxious fumes is reduced to a minimum.

The equipment needed for the submerged-arc process includes a wire-feeding mechanism, a current control station, power supply, a flux feeding device and a flux recovery unit as shown in Fig. 1.

Normally, a bare coiled wire is used as the electrode which is fed automatically into the weld puddle by a variable speed motor which is controlled either electronically or by straight voltage exciter controlled equipment. Coated coiled wire or bare wire in straight lengths are also used in other applications. Power supply can be either ac or dc and should have ample capacity for long duty cycles at high current densities.

Amperage, voltage, diameter of wire and relative motion between the workpiece and the automatic welding head all play an important part in determining the appearance, penetration and quality of the weld. Since the arc or molten weld metal cannot be seen, methods of guiding the automatic head must be devised by mechanical indicators. A projected spotlight beam or mechanical pointer will guide the electrode in the proper relationship to the joint. This is very important to the process and the author will relate to it later on.

Selection of Equipment

Before automatic equipment is purchased, a careful survey should be made of the job it is to perform to determine:

A. Materials to be welded
B. Size and shape of product
C. Production rates necessary
D. Accessibility of the joints
E. Flexibility of equipment
F. Comparative cost
G. Maintenance required

Various types of automatic welding equipment commercially available today make it possible to select the optimum apparatus for the job. We find electronic controlled equipment and d-c motor generator exciter controlled equipment the best combinations. Both types weld almost identically; however, there is a major difference in initial cost and maintenance.

Some types of equipment will take any size wire from $^3/_{32}$ in. diameter up to and including $^1/_4$ in. diameter without necessitating any disassembly of the wire-feeding mechanism. Others require a change of electrode drive rollers, contact jaws, wire guides, etc. Changes of wire sizes are often necessary due to varying material thicknesses and welding procedures and so should be considered in the selection of automatic equipment to assure change-over without excessive downtime.

Selection of positioning equipment to accommodate the product should also be considered at the same time because motion between the welding head and workpiece is of the utmost importance.

In welding pressure vessels, it is essential that the travel carriage and turning rolls be controlled from the operator's station. Any variance in fit or out-of-roundness can then be remedied by either slowing down or speeding up the workpiece to obtain the required weld deposit. With such controls, the operator can move other seams on the vessel into position and weld them without leaving his station.

The welding head support should be constructed to give the maximum versatility and also be rigid enough to prevent any whipping or vibration because such motion will seriously affect the weld. Figure 2 illustrates such an installation.

To assure adequate versatility of the welding head manipulator, the welding engineer must consider all welding aspects of the work which may be required. The author does not believe it is wise to have each station so constructed that it is limited to one set procedure. At a very slight additional cost each station can be made to weld more than one job and thus save many expensive production hours. Also, in the event of a breakdown of the automatic equipment at one station, another station with this flexibility can avoid stoppage of production.

The author would like to add one note of caution to the prospective purchasers of this type of equipment. In the event you have the design of such equipment done by outside engineering firms, be sure that your welding engineer studies and analyzes very carefully the proposed designs. Too often equipment of this type is overdesigned which not only greatly increases the initial cost, but is more complicated to maintain and operate. Keep the equipment as simple as possible.

Edge Preparation for Welding

Preparation of edges of large diameter pressure vessels to be welded is very critical, and special attention must be given to this phase of the fabrication. Plate sizes are usually so large that machining of the bevels is practically out of the question costwise. Therefore, in most cases the edges are prepared for welding by flame cutting while the plate is flat. Due to the waviness of plates, floating torches are used to help keep bevels even, as shown in Fig. 3. Machined bevels,

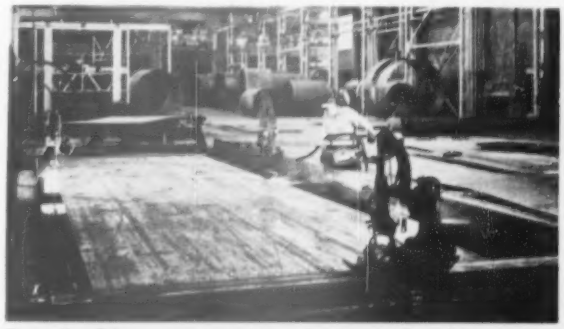

Fig. 3 Edge preparation. Radiographs have three torches for making double bevel and squaring cut in one pass

however, are highly desirable and are used in some instances, especially on alloy pressure vessels. A horizontal planer is one of the machines used to bevel straight plates. Multiple hydraulic clamps are necessary to insure flatness during machining.

It is also desirable to have the surfaces adjacent to the flame-cut edges free from any rust or scale, but this presents quite a material handling problem. Therefore, the plates are normally flame cut, rolled and welded without cleaning. While this procedure is not recommended by the author, the expense involved in grit blasting or grinding the flame-cut edges is prohibitive, therefore, we must depend upon the proper filler wire and type of flux to combat welding defects caused by rust or scale.

Heads for pressure vessels are trimmed in almost the same way as the plates. This operation is pictured in Fig. 4. A horizontal boring mill with a floating torch mounted at right angles to the bed is used in beveling a head. This machine can prepare the edge for welding in one pass, which makes a squaring cut and two bevels.

Joint Design and Setup

Joints for pressure vessels must be designed to make possible welds which will meet operating specifications. Bevels for pressure vessels are in no way different than for nonpressure types. Because of the high currents used with submerged arc welding, bevels can be kept to the barest minimum; the high currents melt the base metal and in turn less filler metal need be added to the joint.

The most important phase of fabrication is the fit of the courses to the shells and courses to the heads. Due to the large diameter of many vessels, it is virtually impossible to get a uniform fit-up prior to automatic welding. A great variation in fit-up generally produces a weld with high stress concentrations, if not followed by postheat treatment. The finished appearance is also impaired by the irregularity of the weld bead.

It is, therefore, necessary that added precautions be taken at the setup stations to provide a uniform joint for welding. This in turn will pay off at the automatic weld station in quality work, and in time saved in rewelding or multipass work on sections of the welded seams. Joint geometry and relative position of joints on the vessels must also meet all code requirements.

Elaborate fixtures are needed to provide uniform joints. However, due to the high costs involved, many manufacturers are still erecting these vessels by the old turnbuckle and clamp methods. Figure 5 shows a fixture for aligning the courses and bringing them in concentricity prior to tack welding.

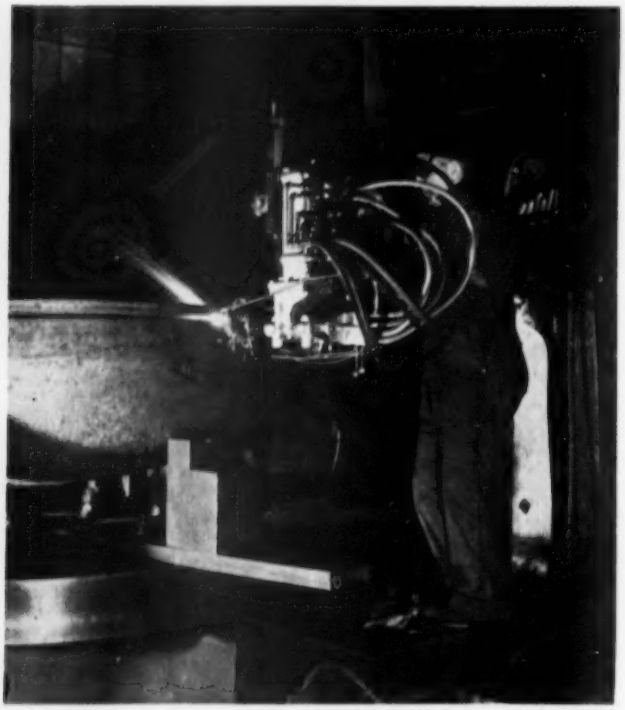

Fig. 4 Precise bevel is cut by flame as tank head rotates

Welding Procedure Specifications

To set up simplified standard welding procedures on pressure vessels poses an almost impossible task. Where a standard line of vessels is built, the problem is not difficult. However, complications do arise in plants where vessels are of different material, stock thickness, diameter and length.

In order to give the automatic welding operator a good welding procedure, it is necessary to include the following information: diameter of electrode, electrode type, flux, amperage-voltage, speed of travel (IPM), number of passes, weld contour or reinforcement and the amount of offset of the electrode on circumferential seams. In order to accomplish this, a separate procedure would have to be issued with each special type of vessel.

Since this may involve considerable time and expense, an average procedure or data sheet can be issued to the operators and they in turn can use this data sheet as a guide to make the proper adjustments of the equipment. After an operator is well versed in the operation of the automatic equipment, he seldom has to consult the data sheet for operating instructions.

When stock thickness is such that a weld from each side can produce a satisfactory weld, the writing of a welding procedure is not too difficult. The welding procedure becomes very difficult where multipass work is necessary because each pass must be numbered and different settings of amperage, voltage and speed of travel on the equipment must be spelled out in the procedure. In the event vessels are of large diameter 10 to 14 ft and made of light plate stock, $^1/_4$ to $^1/_2$ in., they are usually out-of-round or egg shaped. In cases of this kind we rely solely on the operator's judgment to overcome the condition.

One may ask, "Why bother with procedure at all?" Written procedures give three benefits:

1. The welding operator and foreman has at his fingertips a guide as to speed of travel, amperage, voltage, wire sizes, etc.

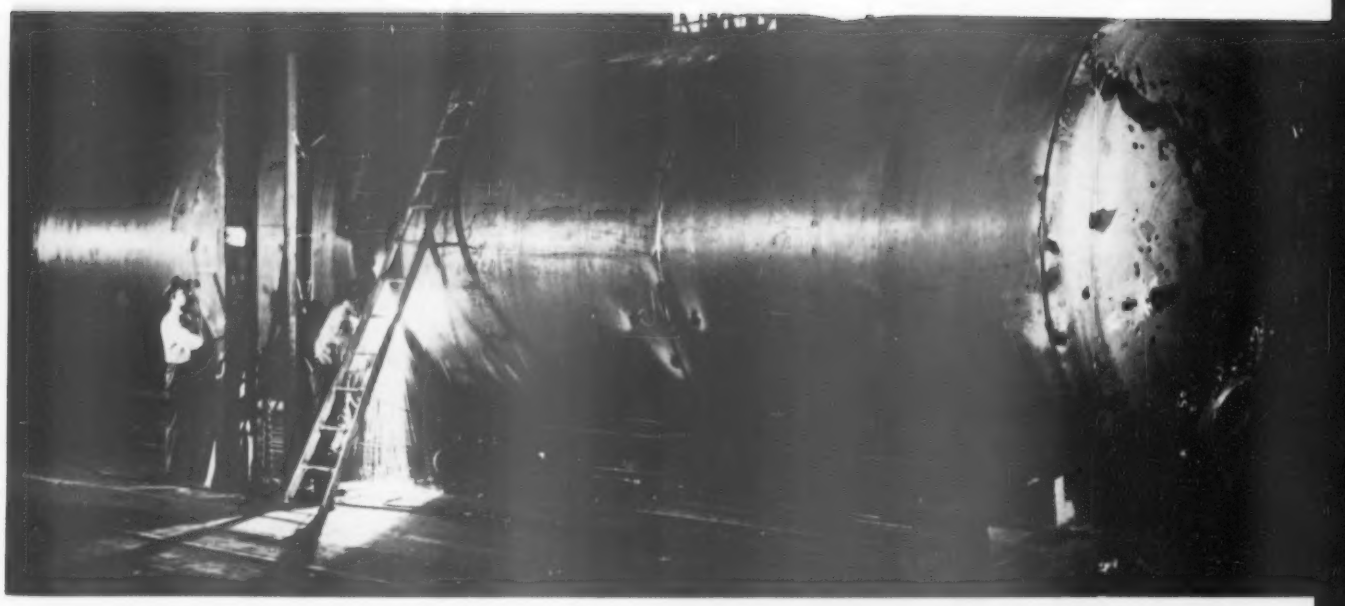

Fig. 5 Fixture for aligning circumferential seams

2. We can place the responsibility for welding directly with the welding engineers who write the procedure instead of with the operator or supervisor.

3. In welding low-alloy steels the type of filler metal can be specified and not left to the discretion of shop personnel.

The procedure should also specify the relative position of the electrode to the joint. On circumferential seams the electrode must be positioned off center to allow for weld puddle drag. If the electrode is not off the vertical centerline of the vessel far enough, the weld metal will pile up or hump up in the center. Conversely, if the electrode is too far off center, a concave weld will be the result with many attendant defects.

The macrophotograph shown in Fig. 6 clearly illustrates what happens when the electrode is not guided properly over the joint to be welded. As mentioned before in the explanation of the process the weld puddle cannot be seen. Therefore, a means of guiding the electrode is very important. Lack of such a guide may be the direct cause of weld defects.

Insufficient penetration is one of the most common sources of weld defects and is usually discernible by small pinholes through the center of the weld. Gas is trapped between the first pass and the second pass and escapes by bubbling up through the solidifying weld metal. Shown in Fig. 6 is a typical defective weld resulting from lack of penetration.

To help in obtaining a uniform joint prior to automatic welding, the joints are inspected after they are tack welded together. In the event openings over $^1/_{16}$ in. are found, buttering passes with stick electrodes are used to prevent the automatic weld puddle from dropping through. In many cases it is customary to backchip, grind or gouge to solid weld metal to insure a top quality weld.

As the shells or courses are taken off the rolls a fast sealer pass is made on the outside of the shell with Class E-6011 electrodes. This serves two purposes. It holds the shell together while being moved to the automatic welder and secondly it provides a sound backup to prevent burn-through with the automatic welder. After the outside is welded, power turning rolls rotate the shell 180° and the weld is then completed on the inside as shown in Fig. 7. This is standard procedure on all longitudinal seam welds.

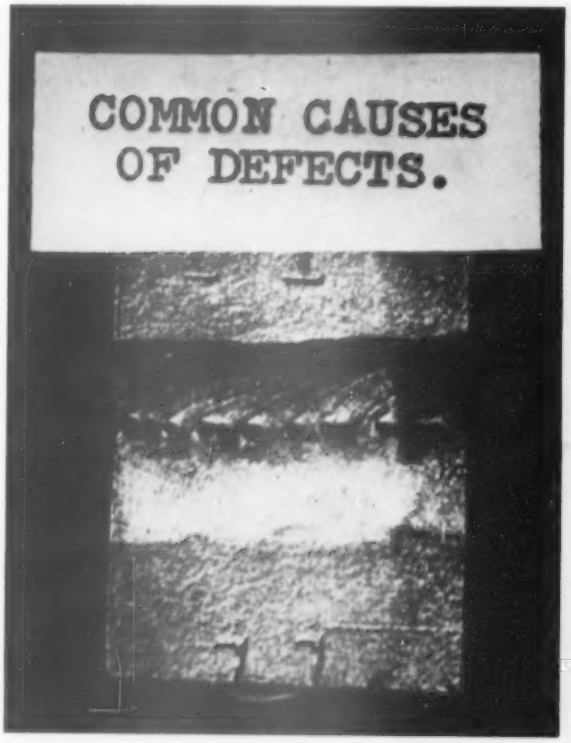

Fig. 6 Pinholes in weld indicate gas entrapment, usually due to inadequate penetration

The circumferential welds are completed in exactly the reverse procedure as the longitudinal welds. Some of the reasons for this reversal are:

1. In the event some sections of the seam need a buttering pass, due to poor fit-up, it is easier and faster for an operator to weld in the interior instead of sitting on top of the vessel or operating from a scaffold.

2. A flatter weld can be obtained on the inside of the vessel which minimizes grinding.

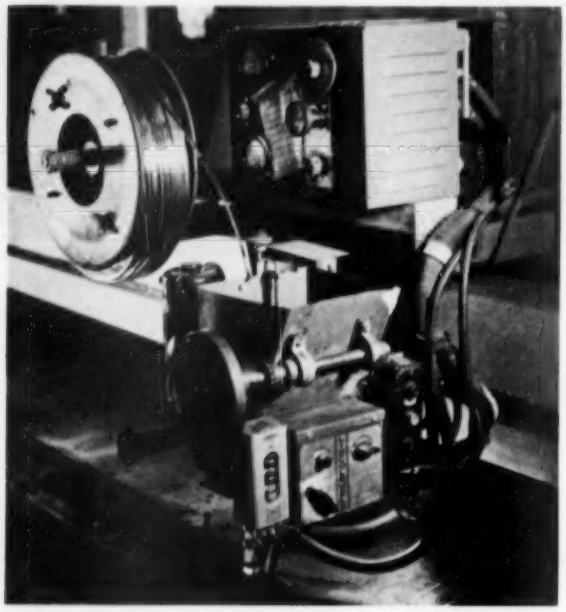

Fig. 7 Completing inside longitudinal seam

Fig. 8 X-ray is sure check of weld quality. Spot checks keep operators on their toes

3. A better quality weld is obtained on the interior due to the annealing action of the outside weld.

4. Backchipping or gouging is accomplished with greater ease on the outside.

Quality Control

Quality control is most important during the fabrication and welding of the vessel. Inspectors have the sole responsibility for either acceptance or rejection of the vessel.

The code to which a vessel is being built determines inspection standards and procedure. Code U-68 specifies X-ray examination of welds. This operation is shown in Fig. 8. It also requires all weld metal .505 tensile tests, transverse tensile tests and root and face bends. Many customers are gradually turning to less critical codes such as U-69 and the 1952 Code.

To keep welding quality at its best, the Inspection Department is expected periodically to spot X-ray vessels as they progress through the factory, whether the job calls for X-ray or not. This procedure serves a double purpose:

1. Production personnel never know when or what vessel the inspector will spot X-ray. Therefore, foremen are constantly checking their own departments for poor welds and attempt to keep operators performing at their best.

2. This procedure somewhat relieves the inspector of very critical and time-consuming inspection. However, it does not relieve him of total responsibility for the vessel.

It is the duty of the welding inspector to mark any defects he deems necessary to repair. Each welder is required to place his stamp or identification number next to any weld he has made. In this way, the inspector can determine whether the individual operator is complying with preset standards.

When X-ray cannot be used, trepanning is acceptable as an inspection method. This method of inspection, however, is costly and after the hole is welded from which the trepanning was taken, the only means of inspecting the welded trepan section are by dye penetrant, or visually. The author suggests X-ray wherever possible.

Conclusion

Due to the numerous advantages of submerged arc welding, the use of this process for joining metals is increasing daily. Manufacturers are constantly seeking ways to reduce costs, improve operator working conditions, increase production and gain better quality and appearance. One major way of accomplishing this is to eliminate the operator variable by the use of automatic equipment. Automation has definitely entered the field of welding. The automotive industries are taking full advantage of the savings derived from automatic welding setups.

Submerged arc welding of pressure vessels is widely accepted and meets all code requirements. The author recommends it as an excellent process for pressure vessel welding.

ELECTRODE ACTIVATION FOR INERT-GAS-SHIELDED METAL-ARC WELDING

Addition of extremely dilute, invisible coatings of certain metals and oxides to welding electrodes stabilizes metal transfer and modifies deposition rate, penetration, and size and shape of weld bead

BY A. LESNEWICH

The inert-gas-shielded metal-arc-welding process uses a small diameter electrode which is fed continuously to a gas-shielded arc maintained between the electrode and the workpiece. The shielding gases are monatomic; argon generally is used. Until recently, a stable, spatter-free transfer of material through the arc was possible only with reverse-polarity direct current. Without fluxes or active gases, the characteristics of the arcs were determined solely by the characteristics of the electrode and plate metals and of the shielding gas. The process variables were limited to the wire diameter, current magnitude, travel speed and type of weave employed. Some minor changes in the characteristics were possible with active gas additions but, basically, the welder had to accept as unalterable, reverse-polarity direct current.

Recent developments with the use of extemely dilute, invisible coatings of the alkali, alkaline earth and rare earth elements[1,2], or certain oxides, have proved to be important; such coatings permit a stable metal transfer with alternating current and straight-polarity direct current, as well as reverse-polarity direct current. They permit the deposition rate, penetration, and size and shape of the weld bead to be varied in a predetermined manner. These results are produced without the development of a slag or changing in any way the inert characteristics of the shielding gas. The use of these coatings is not limited to mild steel welding, but is equally applicable to all industrial metals such as copper, aluminum, stainless steels and titanium.

Description of Standard Inert-Gas-Shielded Consumable-Electrode Arcs

An adequate explanation of the effects of wire activation cannot be presented without first describing the various arcs which are developed with bare consumable electrodes. Arc characteristics vary with reverse-polarity and straight-polarity direct current, and with alternating current; each type of power has definite attributes and deficiencies. To appreciate the need for using activated coatings, the arc characteristics of the various inert-gas-shielded consumable-electrode arcs are briefly described.

Reverse-Polarity Direct Current

High current-density reverse-polarity (electrode positive) arcs shielded in argon have characteristics which are completely different from any arcs which were used before 1948.[3] Beyond some critical value of current, which is somewhat dependent upon the electrode diameter and composition, minute drops of metal are projected in line through the arc column at the rate of 200 or more per second. This so-called spray transfer develops the characteristic arc and penetration patterns of the high current-density argon-shielded arc, as illustrated in Fig. 1. Each of the small droplets and the electrode tip are surrounded by a halo of incandes-

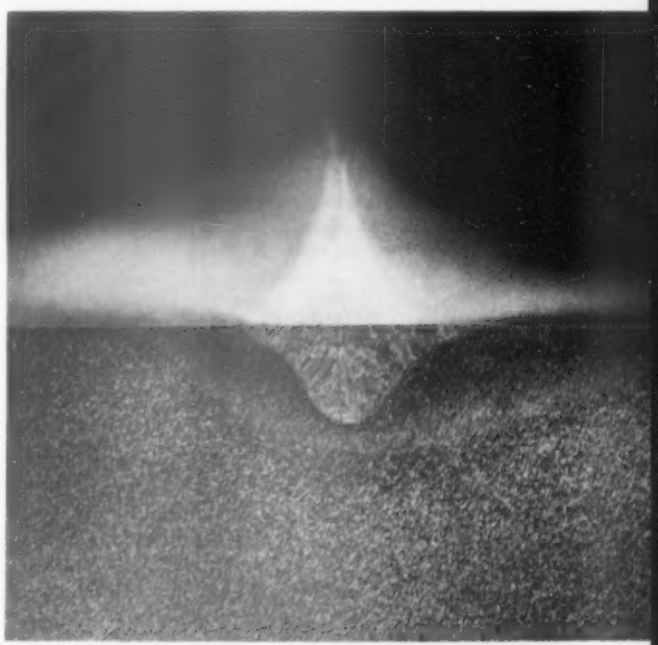

Fig. 1 Typical reverse-polarity arc and cross section of weld—argon, $^1/_{16}$-in.-diam mild-steel electrode, 350 amp, 36 v, 220 ipm melting rate

A. Lesnewich is associated with Air Reduction Co., Inc., Research Laboratories, Murray Hill, N. J.

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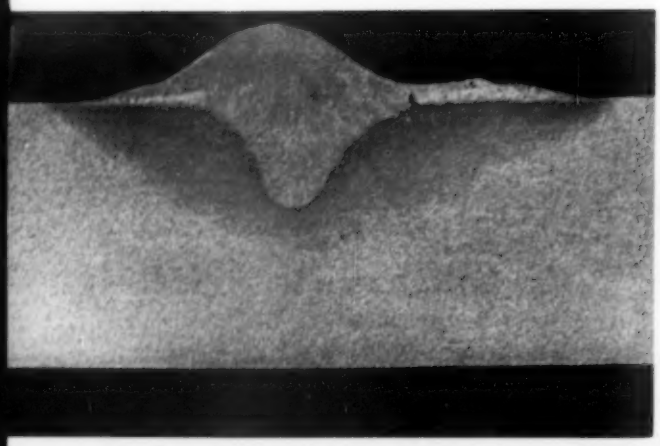


Fig. 2 Typical irregular cross section of weld with reverse polarity—argon, $^1/_{16}$-in.-diam mild-steel electrode, 400 amp, 34.5 v, 260 ipm melting rate

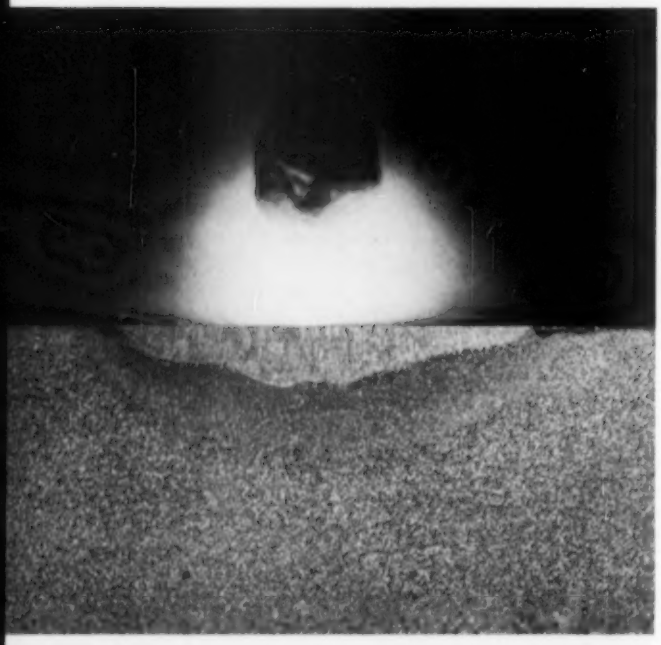


Fig. 3 Typical straight-polarity arc and cross section of weld—argon, $^1/_{16}$-in.-diam mild-steel electrode 350 amp, 37.5 v, 410 ipm melting rate

cent and excited metal vapor which precedes the drops as they travel toward the weld crater. As a result of the rapid rate with which the drops form and traverse the arc regions, this zone of incandescence becomes a needle-like continuum known as the vapor jet. Around the drops and vapor jet is an umbrella of less intensely excited plasma which is composed almost entirely of the shielding gas. This type of transfer does not produce short circuits, and it is associated with almost no spatter. The powerful vapor jet region is extremely penetrating and produces the papillary cross section of weld which is characteristic of this process.

With reverse polarity, a plate phenomenon known as cathode sputtering or cleaning action occurs on the surface of the plate. This action improves the arc welding of aluminum because it destroys the tenacious and refractory oxide surface films and permits the weld metal to wet the weldment surfaces. Under some conditions, sputtering may not be desired because, with steel, its action is not always uniform, being more intense in some areas than others. When this occurs, the arc plasma wanders, the arc is less stable and metal wetting is irregular, as shown by the thin fused surface layer of the cross section, Fig. 2. The localized heat generated by the cathode sputtering action may, ultimately, develop a gouge in the vicinity of the arc and, if sufficient metal is prevented from flowing into these regions while the surface is still molten, undercut is produced. Such undercut is particularly prevalent on the vertical leg of horizontal fillet welds; gravity usually prevents feeding molten metal into this region. The addition of oxygen to the argon shield will minimize this effect, stabilize the arc, develop a more uniformly shaped bead, and somewhat reduce the undercut; achieving, in some instances, complete absence of undercut.

Straight-Polarity Direct Current

A stable, spray transfer cannot be produced with untreated wire using straight-polarity (electrode negative) direct current even at high current densities. The sputtering or cathode action found at the plate with reverse polarity occurs at the electrode with straight polarity; therefore, the reverse-polarity effects of undercutting and irregular wetting of the bead toe are no longer problems. Instead, the cathode action releases energy at the electrode and causes the wire to melt at almost double the reverse-polarity rate. A broad arc plasma, with indistinct boundaries, forms between the tip of the electrode and the plate; the cathode forces on the molten end of the electrode are so great that the drops which form are supported against gravity. As a result, the force of surface tension is not overcome by electrical pinch effects and large drops form and are transferred randomly by gravity at the rate of only a few per second. Their erratic motion causes the arc plasma to shift, and, as a result, the weld becomes broad with small penetration; many of the drops are accelerated away from the weld by the cathode action and form spatter. Spatter also is developed by mechanical agitation and the explosion of large short-circuited drops which touch the plate before they are parted from the end of the wire. A typical straight-polarity arc and its related weld cross section are illustrated in Fig. 3.

At a first glance, the high melting rate and low penetration of straight polarity would appear to make it ideal for overlay applications. However, the spatter and instability of these arcs are strong deterrents to their use.

Alternating Current

Alternating current for welding presents more problems, in addition to those of transfer, spatter, deposition rate or penetration which are encountered with direct-current welding. The cyclical change from reverse to straight polarity at the conventional frequency of 60

cps causes the development of a smooth, stable spray arc for $^1/_{120}$ sec, and a spattery, large drop condition for the other interval of each cycle. These reversals in polarity require the current to pass through zero 120 times per second; causing the arc to be extinguished each time. A useful welding process requires the arc to be reignited without recourse to actual contact of electrode and plate or the superposition of a high-voltage impulse.

Arc reignition of untreated electrodes requires the high voltage, low-current phenomenon known as the glow discharge, which triggers the low-voltage, high-current welding arc discharge. Glow discharge voltages are highly dependent upon the composition and temperature of the cathode and the nature of the shielding gas. In general, they need at least 100 v and may require more than 250 v; the current flow is on the order of 1 amp. It is fortunate that the circuit impedance of the transformer and welding arc is such that the open-circuit voltage leads the arc voltage by almost 90°; supplying a peak voltage at precisely the time when it is most essential.

However, in spite of this, conventional transformers with 75-v rms open-circuit outputs are not able to establish a glow discharge with most argon-shielded welding arcs. For example, when attempting to maintain a 390-amp mild steel arc, the voltage signals, Fig. 4, available from a 75-v rms transformer will not maintain a stable arc, whereas the voltage signal from a 150-v rms transformer will maintain a satisfactory arc. Obviously, the 200-v glow discharge spike available with a 150-v transfer, makes possible good restriking and thus good arc stability. Welding other metals, such as aluminum which requires more than 210 v to initiate a glow discharge, requires even greater no-load or striking voltages.

Figure 4 also illustrates the temperature dependency of the cathode on glow discharge; a lower voltage is required to ignite the arc when the cathode is the superheated wire than when the relatively cool weldment is the cathode.

With a stable alternating-current arc, good transfer occurs only during the reverse-polarity intervals; spatter and instability are associated with the straight-polarity interval. In general, the melting rates are an average of the rates for straight and reverse-polarity direct current. The arc penetration also is an average of that of the two polarities.

Alternating-current arcs, even though they must be sustained with high voltages using bare wire, are of considerable advantage for ferrous welding applications because they minimize the problems aggravated by magnetic fields and arc blow. On the other hand, such arcs may have spatter problems because of arc instability with some welding conditions, and there is always danger to the welder because of the need to use excessive open circuit voltages.

Evolution of Activation

The inert-gas-shielded consumable-electrode process is used with reverse-polarity direct current in spite of some minor deficiencies; most of these are resolved with the addition of active gases or minor modifications of welding techniques. Because the few advantages of straight-polarity direct-current and alternating-current arcs are so outweighed by serious disadvantages, these types of power are rarely used. The commercial approach to straight-polarity welding has been the use of active gas additions to improve arc stability; however the suitability of such additions is highly questionable because they cause excessive oxidation of critical alloying elements.

A close examination of the objectionable characteristics of all polarities indicates that they are the result of cathode phenomena. For example, poor transfer occurs when the electrode is negative, sputtering and poor bead contour develop when the weldment is negative, and arc instability with alternating current is produced because high voltages are required to establish glow discharge (a cathode phenomenon) when the plate or electrode becomes negative.

It is postulated that the arc plasma is maintained by a flow of positive ions and electrons which, initially, have as their source the arc anode and cathode. The electrons can be evolved as the result of two mechanisms. One of these mechanisms is termed cold cathode emission; it is not understood and all explanations of it are speculative. The other, thermionic emission, has been explained and an equation for calculating such emission was developed as early as 1903. Calculations based upon thermionic emission indicate that the therm-

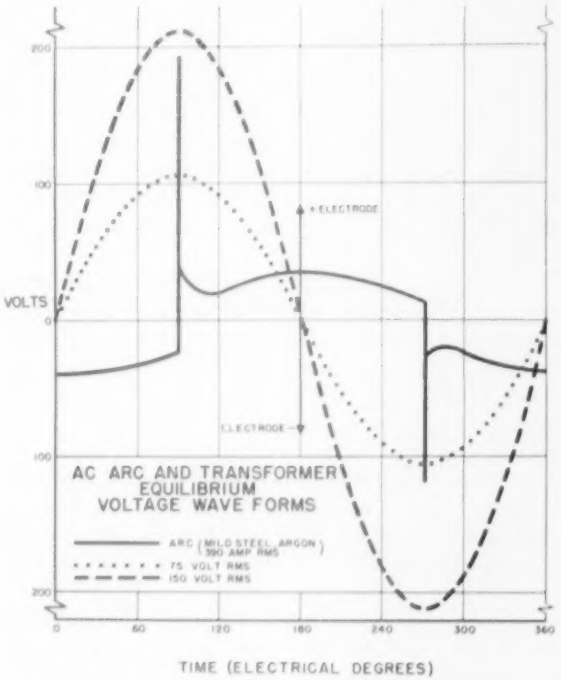


Fig. 4 Wave forms of both arc and open-circuit voltage when welding mild steel with alternating current in an argon shield

of tungsten, yet tungsten is known as a thermionic ma-

ionic emission current is not of sufficient magnitude to sustain a welding arc with the structural metals. This leaves but one postulate explaining the cathode phenomena of the welding arc. If the cathode could supply more electrons by thermionic emission, the cold cathode reactions would be minimized and, conceivably, improvement in arc stability might result.

The following paragraphs will develop the mechanisms which can be utilized to achieve an increased thermionic emission and, subsequently, the application of these mechanisms to the inert-gas-shielded welding arc will be given.

Thermionic Emission—Pure Metals

Metals are crystalline in nature; they consist of a three-dimensional array of atoms formed by the regular repetition of some fundamental structural unit. The atoms are located so close together within these crystals that their outer electrons are as much associated with one atom as another and can be considered to wander freely about as an "electron gas." If some barrier to the electrons did not exist at the metal surface, they would escape to the atmosphere in great numbers, and the metal lattice would become highly charged and eventually disintegrate. As a gross simplification, this barrier can be considered to develop when an electron attempts to leave the metal. When it leaves, it induces a positive charge within the metal which is equal to itself in magnitude. This induced attractive charge tends to overcome the motion of the electron away from its parent lattice and causes it to return. Other, more complex forces also act upon the electron to keep it from leaving; in combination, they form a barrier whose intensity is measured as the energy in electron-volts (eV) required to move an electron from the metal surface to infinity. This energy, called the work function, is dependent upon the magnitude of the electric field outside the metal surface, upon the orientation of the surface to the underlying crystal lattice, and, to a slight degree, upon the temperature of the metal. Normally, it is considered to be a constant for each metal in question, and is usually represented by the symbol ψ.

As a greatly simplified analogy,[4] the free electrons can be represented by balls which are running up an inclined slope of a height equivalent to the metal work-function. The velocity of each ball differs statistically about some average and increases with rising temperatures. At low temperatures, most of the balls will run up the slope to a certain height and then return because their velocities are too low to reach and surpass the rim. Only a very few balls, whose velocity is especially large, will reach the top and not return; these represent the emitted electrons. An increase in temperature will increase the average velocity and enable more balls to reach the top of the slope, demonstrating the increase in electron emission produced by a higher temperature.

Richardson,[5] in 1903, used statistics to develop an equation for the thermionic emission of electrons as a function of the temperature and condition of the emitting surface. Thermodynamic principles later were used by Dushman[6] to derive an equivalent but more useful expression since, for perfect materials, it does not contain empirical constants. The equation

$$i = AT^2e - \frac{11{,}600\psi}{T}$$

defines i, the saturation current-density in amperes per square centimeter or the maximum possible emission from a unit area of surface in terms of the absolute temperature T (°K) and work function ψ (eV). This condition of saturation is possible only when all of the emitted electrons are removed from the vicinity of the cathode; if they are not removed, their accumulation as an electron cloud produces a retarding force which keeps other electrons from leaving. The removal of the electrons is accomplished by impressing a voltage of sufficient magnitude upon the cathode. A is a constant which has a theoretical universal value of 120 for pure surfaces of single crystals. More often, it has the value of 60 and for many metals has some still lower value. As with many so called constants, A and ψ are not fixed but are somewhat temperature dependent.

The magnitude of the saturated thermionic electron current depends upon the values of work function and temperature to a high degree. This dependence is illustrated by the curves of Fig. 5 which satisfy the above thermionic equation for $A = 60$ and $\psi = 1, 2, 3$ and 4. These curves show that adequate low-temperature emission is possible only with cathodes which have low work functions (i.e., at 2000° F; 0.001 amp/in.^{2} with $\psi = 3$, but 100,000 amp/in.^{2} with $\psi = 1$); those cathodes with high work functions can supply the same quantity of electrons only at high temperatures (i.e., for 100,000 amp/in.^{2}; 2000° F with $\psi = 1$, but 7000 ° F with $\psi = 4$).

Most metals have high work functions; consequently, such metals can act as a good source of electrons only if heated to very high temperatures which are far in excess of their boiling points. Aluminum and iron have work functions which are lower than that

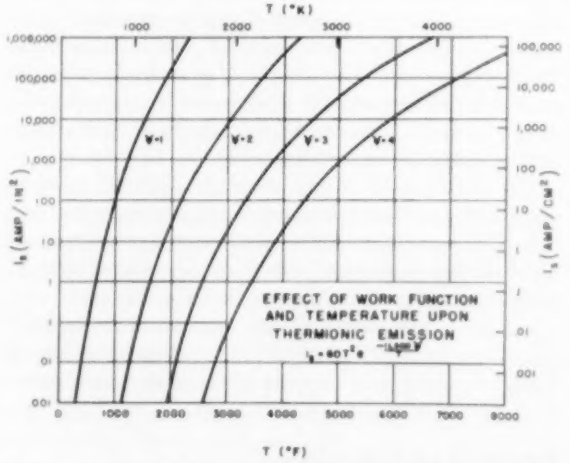


Fig. 5 Effect of the work function and temperature of a surface upon its thermionic electron emission

of tungsten, yet tungsten is known as a thermionic material because it has a high boiling point which permits it to be heated to a high temperature without being dissipated into vapor. It is this physical characteristic which makes tungsten useful as a nonconsuming electrode for inert-gas-shielded welding. This major difference in the behavior is shown by comparing their thermionic emission curves, Fig. 6. These curves are plotted to show the emission developed by $^1/_{16}$-in. diameter electrodes of iron, aluminum and tungsten at temperatures up to 9000° F. All three materials exhibit an equivalent emissivity below 3740° F, but aluminum boils at this temperature, and for this reason, its electrode cannot provide more than 0.01 amp of thermionic electron current to the arc. An iron electrode can develop a maximum of one ampere at its boiling temperature. Tungsten is highly refractory; it does not melt until heated to over 1000° F above the boiling point of iron. At its melting temperature, a $^1/_{16}$-in. diameter tungsten electrode can provide 10 amp of thermionic electron current. In practice, more thermionic electron current is drawn from these electrodes by heating them above the melting point; their maximum useful output is approximately 100 amp for $^1/_{16}$-in. diameters. This current limit is dependent to a large degree on the cooling possible in the electrode holder; if the cathode heat and resistance heating in the tungsten extension is not extracted adequately, the extension becomes progressively shorter until the arc strikes the holder.

It is not surprising that the operable range of tungsten is shown to be above its melting point; tungsten electrode tips generally become rounded during service. The illustrated curves assume emission from a plane surface, whereas the effective cathode area is defined by the spherical surface enveloped by the plasma; the band of normal operating range of Fig. 6 should be shifted therefore, to a lower level of current density to account for the larger surface area. The tungsten electrode at straight polarity can maintain a welding arc and the cathode current flow through the plasma of

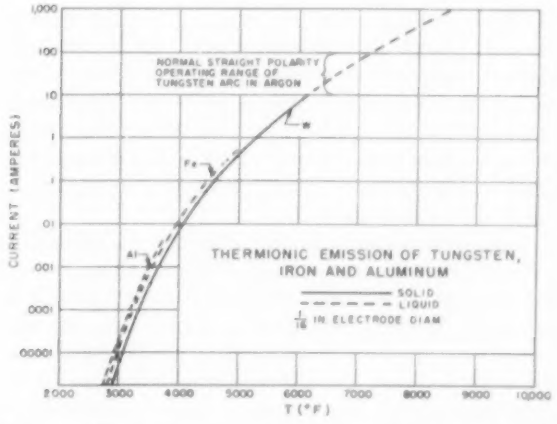


Fig. 6 Effect of temperature upon thermionic electron emission from $^1/_{16}$-in.-diam tungsten, iron and aluminum electrodes

Table 1—Thermionic Emission of Some Metals

Metal	*Work Function, ψ, eV*	*Melting point, ° F*	*Boiling point, ° F*	*Thermionic emission, amp/in.²* *Mp*	*Bp*
Copper	4.45	1981	4,700	6×10^{-6}	1
Magnesium	3.67	1202	2,030	8×10^{-12}	7×10^{-2}
Aluminum	4.20	1220	3,740	2×10^{-16}	4×10^{-3}
Molybdenum	4.24	4760	8,670	3	2×10^{-4}
Tungsten	4.54	6170	10,700	80	7×10^{-4}
Iron	4.49	2802	4,960	1×10^{-5}	3
Nickel	4.96	2651	4,950	9×10^{-6}	0.4

such arcs can be accounted for by thermionic emission.

On the other hand, the cathodes of iron and aluminum are able to supply almost no thermionic electrons; it is for this reason that they are called cold cathode metals. Most structural metals fall in this category; they have high work functions and are able to supply only a small number of thermionic electrons to the welding arc. The electron emissivities of some metals at their melting (Mp) and boiling (Bp) points are given in Table 1 for purposes of comparison; those with low emissivity must have some mechanism other than thermionic emission functioning in their welding arcs, otherwise, such arcs could not exist.

Atomic Film Cathode—Thermionic Emission

The emission properties of a pure metal may be changed considerably if atoms or ions of other elements are adsorbed at its surface. This fact was discovered by Langmuir in 1914,[7] after adding about 1% thorium oxide to tungsten wires for improving their metallurgical behavior in incandescent bulbs. Thorium oxide dissociates to thorium and oxygen at temperatures above 4000° F; this thorium and oxygen diffuse to the tungsten surface. The thorium forms a film and the oxygen is released to the bulb atmosphere. It is generally accepted that the thorium atoms lose their shell electrons to the electron cloud of the tungsten and are then held as positive ions to the surface by image-force attraction. This adsorption of positive ions produces a double layer consisting of a layer of positive ions on the surface and a layer of negative charges induced between the metal and positive ions.* Such a double layer produces a marked reduction of the metal work function. The attractive forces of the adsorbed layers are so great that the ions of a given element are retained at temperatures far above the boiling point of the element.

Another explanation for the reduction of the work function assumes that the adsorbed particles are electrically neutral as a whole, but become so distorted by the forces holding them to the surface that they form electrical dipoles. These dipoles, if oriented with their positive poles outward, will also form an electrical double layer which reduces the surface work function.

* These positive ions can form without absorbing external energy if their ionization potential is less than the work function of the metal upon which they are deposited. When this relationship is satisfied, transference of electrons from the atom film to the underlying surface can cause a release of energy.

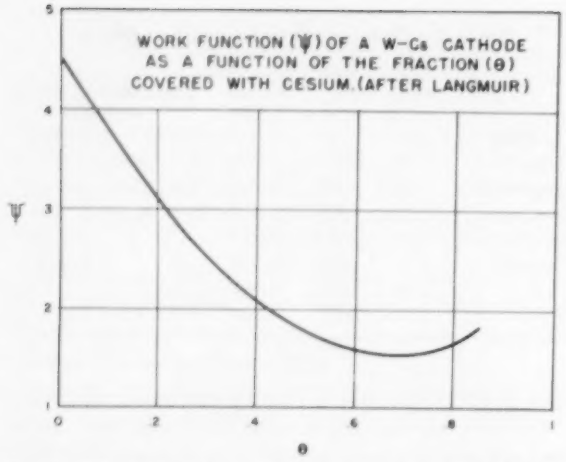


Fig. 7 Effect of cesium additions to a tungsten electrode upon the thermionic emission of electrons from the electrode. (After Langmuir)

Table 2—Work Functions of Some Atomic Film Cathodes

Surface	*Work function, ψ, eV*
W	4.54
W-Cs	1.6
W-Ba	1.56
W-Th	2.63
W-O	6.24

If such dipoles are developed with their negative poles directed outward, the work function will decrease. This result is produced sometimes by adsorbed gases, particularly oxygen.

The effect of absorbing a cesium surface on tungsten also was studied by Langmuir and his co-workers.[8] They showed that cesium will reduce the work function of tungsten; the degree of activation being strongly affected by the extent to which cesium covered the surface (Fig. 7). Other investigators[9] agree with this curve in principle, but feel that the maximum activity occurs when a single complete layer forms and that diminished activity results when a second layer forms. Table 2 lists the optimum values of work functions which are possible with some atomic-film cathodes. This table shows the work function of an oxidized tungsten cathode to be considerably higher than pure tungsten.

Composite Surface Cathodes

It is possible to improve the very low emissivity of an oxidized tungsten cathode by condensing upon it a layer of cesium. Surprisingly, the work function of this composite surface is even below that of a tungsten-cesium cathode. Although many authors will classify this surface as an atomic film, it seems that the term "composite surface" is more appropriate. The most logical explanation for this improvement in emission[10] assumes that the cesium ions become located at the end of the metal-oxide dipoles and are more tightly bound to them than by simple adsorption on a clean metal surface, thereby forming a double layered surface consisting of absorbed oxygen on the metal and absorbed cesium on the oxygen layer. As a result of the electrical arrangement of the binding forces, a more efficient surface for electron emission can be produced, i.e., one with a lower work function. More important, these surfaces are stable at higher temperatures, and, consequently, can be made to provide considerably more electrons than a simple metal-atomic-film cathode. The same effects noted with cesium have been observed with barium on tungsten oxide, and it is expected that the same mechanism would be applicable to composite surfaces on other materials.

Table 3—Work Function of Composite Surface Cathodes

Cathode	*Work function, eV*
W-O	6.24
W-Cs	1.6
W-O-Cs	1.4
W-Ba	1.6
W-O-Ba	1.3
W-Ba-O	2.5

If composite surfaces are exposed to oxygen after their development, a poisoning of the cathode is effected. With time, however, the oxygen can migrate to the substrata and the characteristics of such a surface are again decidedly improved. Table 3 illustrates the reduction in work function which is possible with composite surfaces and the poisoning which is produced with oxygen.

Activated Oxide Coating

The emission properties of certain metallic oxides were discovered in 1903 by Wehnelt;[11] the present oxide cathodes of radio tubes are a direct outcome of these experiments. As with the metallic atomic-film cathodes, a number of theories were evolved to explain the behavior of the oxide film cathodes, but it was not until the physics of semiconductors was understood that a really satisfactory explanation for the mechanism could be given.[12, 13]

The theory assumes a coating of oxides with a thickness having a lower limit of about 400 atom layers. When activated at temperatures exceeding roughly 1000° F, a partial dissociation of the oxide occurs; this releases the oxygen and leaves an excess of metal within the coating, and, to some degree, on its surface. As a result of the oxide deficiency, lattice defects are produced and an electron cloud having characteristics of that of metals is developed.

The free electrons can be removed from the suboxides by thermionic emission because of lower work functions. The number of electrons removed can be calculated with the Richardsen-Dushman equation, if the dependence of work function upon temperature is considered. The work function of these oxides is dependent upon the constitution of their interior; that is, the thermodynamics of their thermal dissociation, its temperature dependence and the catalytic effects of its surface chemistry. At operating temperatures, the suboxide

materials are excellent electrical conductors, and, in opposition to metals, have a negative temperature coefficient of resistivity.

The work function of an oxide cathode is not uniform along its surface; electron photographs of oxide films show that different areas emit with different intensities. These emission centers do not form at random but are directly affected by the following:[14]

1. Differences in the oxide coating thicknesses between different areas.
2. Variations in the size and configuration of the pores of the coating.
3. Differences in the coating roughness.
4. Differences in the orientation of the emitting surface area, particularly with reference to the crystal system.
5. Possible variations in the coating analysis.

Some values of the work functions of different oxides are given in Table 4. Due to the fact that suboxide formation is temperature dependent, the work functions are temperature dependent; therefore, the temperature at which each value applies is also given. This table illustrates that low work function oxide cathodes are not restricted to the alkaline earth metals, but may develop if metal oxides become suboxides after a suitable activation treatment. These oxides are useful only if activation can occur at some level of temperature which is below the temperature at which the oxide completely dissociates into pure metal and oxygen so rapidly that the oxide is destroyed.

Thermionic Emission in the Welding Arc

Although the theories just presented have had most of their application in the development of cathodes for electron tubes, they can be used to explain certain phenomena of the welding arc, and to modify the welding cathode to the advantage of the welding engineer. Naturally, a number of differences in the behavior of these cathodes must be considered; the phenomena which occur in one case cannot necessarily be expected to be observed in the other.

In the electron tube, the base metal, the coating and the operating temperature can be selected to obtain the most effective surface characteristics to satisfy the demands of a specific application. This surface works either in a vacuum or in a gas atmosphere of very low pressure. The proper crystal structure can be developed with activation at temperatures above the expected operating temperature. The surface is easily protected from those elements which could poison it and cause a marked reduction in its emission.

The welding cathode, on the other hand, is required to develop current densities which are on the order of one thousand times greater than those of the electron tube. The core wire is selected for the welding application rather than for optimum emission. The coating material is selected to match the core; it must be efficient at temperatures which are in excess of the melting temperature of the electrode. Economics dictate that the necessary decomposition and reaction with the core be produced along the electrode as it is fed to the arc. Fortunately, the welding arc operates at atmospheric pressure, raising the boiling temperature of the activated surface far beyond that within a tube. In addition, the coating is being continuously replenished and need have only a very short effective life. It is only because a higher operating temperature is possible and a short life is required that an activated welding cathode can supply electrons in quantities far greater than practical in radio tubes, or with nonconsumable welding electrodes.

The increased thermionic emission of the cathode also modifies other mechanisms of the arc to develop increased alternating current stability and improved material transfer, as well as a general improvement in arc stability; less fluctuations in arc length, and current and voltage magnitude. These effects are particularly important to the consumable-electrode processes and can be used to improve the art of welding. They have been used with covered-electrode and tungsten-electrode welding in the past.

Many of the compounds and minerals added to the washes and heavy coatings of covered electrodes serve to do more than add alloying elements, provide protective gases or slags, or direct the motion of material in transfer. They serve to modify the electrode emissivity, allow a transfer of metal droplets with fewer short circuits and permit the use of alternating current machines with low open-circuit voltages. The proportion of each ingredient required is sometimes critical because an undesirable reduction in the melting rate may develop as additions are made to alter metal transfer or increase arc stability.

The development of thoriated-tungsten electrodes for the inert-gas-shielded-arc process[15] was based upon Langmuir's experiments of 1914.[7] These electrodes have reduced work functions which permit them to supply a given current at lower electrode temperatures or a higher current from a thoriated electrode having the same temperature as a pure tungsten electrode. A number of other advantages also are obtained. The increased emission is developed as the result of atomic-film activation. Thorium oxide within the tungsten rod is decomposed at the operating temperature of the electrode, and the thorium diffuses to the outer surface. Some of it evaporates; the rest develops a film of thorium atoms and electrons. An equilibrium surface concentration is reached which balances the rate of diffusion toward the tungsten surface and the rate of

Table 4—Metallic-Oxide Work Functions

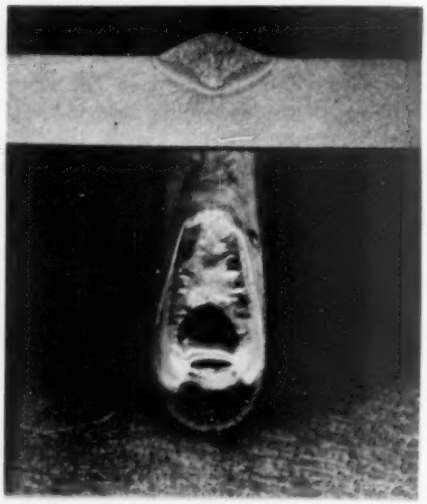
Oxide	*Temp., ° F*	*Work function, eV*
BaO	930	1.65
SrO	930	2.07
CaO	930	2.37
Cs_2O	260	1.0
Mg_2O	2050	3.1
Al_2O_3	2050	4.7
ThO_2	2050	3.9
ThO_2	2950	2.6

evaporation and diffusion away from the same surface. Although this surface never attains the uniformity of coverage or the purity of Langmuir's electrode for which he found the optimum thoriated tungsten work function to be 2.63 eV, the commercial thoriated electrode, nevertheless, does have a work function which is less than that of a pure tungsten and does supply more electrons to the arc at any given temperature.

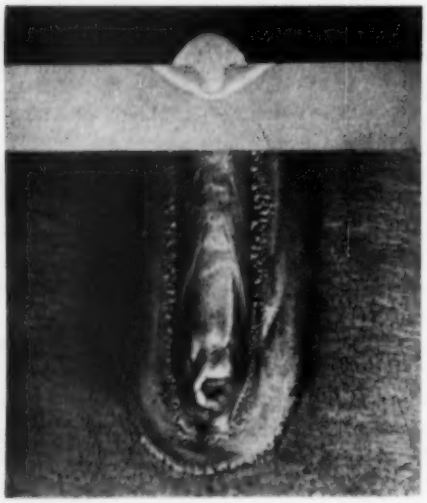
The reduction in temperature for any given cathode current density is obtained by two mechanisms. First, a chilling effect is produced by the evaporation of electrons in a manner exactly equivalent to the cooling of human bodies by evaporation of perspiration. Possibly more important is a change in the ratio of positive ions to electrons required to maintain the flow of current through the arc plasma for the same total arc voltage. Since electrons are easily available at a lower cathode voltage, more voltage is available to accelerate them across the arc and thus fewer positive ions are required to sustain the arc; consequently, the arc is maintained with less positive ion bombardment of the cathode through a smaller cathode voltage drop, and thus less cathode heating. Looking at it another way, lowering the work function creates a new temperature equilibrium, and a different positive-ion/electron ratio is established.

Thorium is not the only material which will improve the emissivity of tungsten. Zirconium-activated electrodes are on the market and calcium, yttrium and other elements[16] also may be added to tungsten to

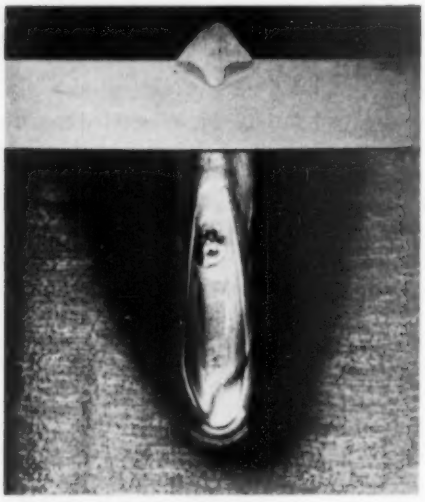
(a) 99.9% argon—33.3-v
untreated electrode



(b) 98% argon + 2% oxygen—30.7-v
untreated electrode



(c) 99.9% argon—25.5-v
rubidium-treated electrode



(d) 99.9% argon—23.5-v
barium-treated electrode

Fig. 8 Effect of plate activation upon cathode sputtering and cross section of mild-steel welds—reverse-polarity direct current, 270 amps, $^{1}/_{16}$-in.-diam electrode, 235 ipm melting rate, $^{3}/_{16}$-in. arc length

reduce its work function and improve performance.

The mechanism of oxide emission has been applied inadvertently with oxygen additions to the inert-gas-shielded welding processes for improving the characteristics of the arc with a consumable steel electrode. A basic deficiency of mild steel welding in pure argon was the uneven wetting and undercut which developed using reverse polarity, particularly with currents in excess of 350 amp. Both of these effects and the poor metal transfer associated with straight-polarity welding are manifestations of a cathode phenomenon known as sputtering. The mechanism for sputtering is complex; it is the result of a number of reactions within the arc stream and at the cathode. It can be minimized by the formation of a heavy film of iron oxide, which can supply electrons to the arc by oxide emission.

A machined steel surface is not free of iron oxide since the oxide forms to some degree upon contact with the atmosphere; this thin oxide can supply only limited thermionic electrons to the arc, and it is felt that emission does occur at the outer fringes of the plasma which contact the weldment when it is the cathode. Since oxide emission is so affected by a number of variables, the current drawn by fringe emission would tend to be highly localized at numerous points. The concentration of current at these points causes the emitting oxides to be heated by their own resistance, and, because of a reduction in work function, to supply more electrons until, by cumulative reactions, the oxide is heated beyond its decomposition temperature and destroyed. During this process, the strong localized emission causes gases in the vicinity to become excited or incandescent and produce the flashes which are characteristic of sputtering. The area within this fringe becomes etched and relatively free of oxides, but it can supply an appreciable thermionic electron current since the current density required of the fringe area is in the order of only 50 amp per square inch. However, with a current demand beyond some critical amount, thermionic emission alone cannot supply the means for maintaining the arc, and, therefore, more cations are developed which strike the cathode at localized points within the plasma umbrella. Cold cathode reactions produce an incipient melting and conical protuberances around the weld crater. It is these regions of incipient melting which accept the weld metal and cause a very uneven bead toe to develop at reverse polarity. Both the surface etching and incipient melting developed on a clean plate are illustrated in Fig. 8*a*.

If the weldment surface is sufficiently oxidized with a residual mill scale or by oxygen additions to the argon to effect reduction in the plate surface work function, a thermionic cathode develops which supplies enough electrons to maintain the arc with a reduced sputtered area and less incipient melting. The resultant deposit is definitely more regular, and, because of a restricted, uniform cathode, the arc is more stable. The improvement produced with 2% oxygen additions to argon is illustrated in Fig. 8*b*. An added proof that improved thermionic emission from the weldment causes the elimination of sputtering is the fact that elements which form an atomic-film cathode with iron will produce the same or a stronger effect than iron oxide. Typical cross sections of two atomic-film-stabilized reverse-polarity beads are shown in Figs. 8*c* and 8*d*.

The weld beads illustrated in these two figures have heat-affected zones which are noticeably more confined than those deposited with untreated electrodes. Since the electrode is positive, its melting rate and penetration are not affected by any activating treatments. However, on the plate, the restricted areas of cathode reaction and colder plate surfaces cause the bead widths to become confined, and, with equal deposition rates, necessarily higher. The deposit illustrated in Fig. 8*c* could have been broadened with oxygen additions to the argon shield.

At straight polarity, it is impossible for a clean wire to support an arc with thermionic emission since its area of emission is confined and its work function is high. It might be deduced that positive ions perform most of the function of maintaining a flow of current through such arcs. These particles are caused to approach the cathode in great numbers since only some of them will be able to accept electrons upon impact. The greater majority of the positive ions, however, may not be neutralized but impart some of their kinetic energy in the form of heat and mechanical energy. It is this energy which supports the drops of Fig. 2 against the force of gravity.

A film of iron oxide on a steel electrode, formed by a sulcoat or heat-tinting treatment or with oxygen additions to the argon shield, will cause more thermionic electrons to be supplied to the arc. Fewer positive ions are then required to sustain the arc and so their effect upon the cathode decreases; with straight polarity, the reduced flow of positive ions to the cathode reduces the

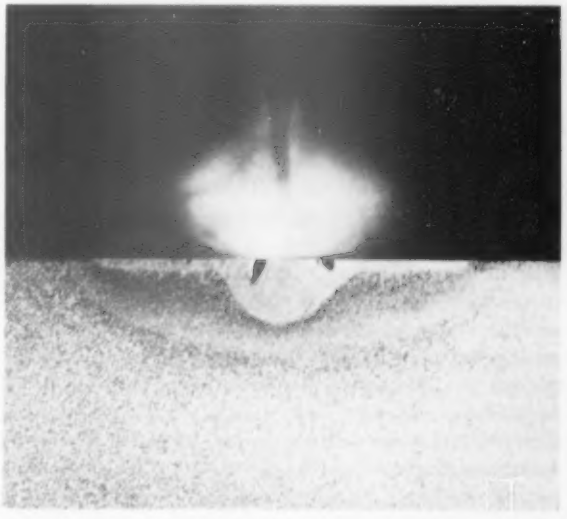


Fig. 9 Typical effect of 5% oxygen addition to argon upon the arc and cross section of the weld in straight-polarity welding—$^{1}/_{16}$-in.-diam mild-steel electrode, 350 amp, 30.5 v, 380 ipm melting rate

energy developed there and this in turn causes a reduction in the wire melting rate and an improvement in metal transfer as shown in Fig. 9. With straight polarity, a thermionic arc discharge becomes possible from cooler regions of the wire cathode, the plasma climbing to some high equilibrium point depending upon the area required to sustain the arc by thermionic emission with a minimum expenditure of energy. Such stability can be developed with oxygen additions to the argon at the expense of some oxidation of alloying elements. Although improving the straight-polarity material transfer and the reverse-polarity bead contour, the iron oxide emission is inadequate for alternating-current stability with low open-circuit-voltage transformers. Iron oxide is not the only oxide which develops suboxide emission; titanium oxide, which is so common in covered electrode coatings, causes a material transfer somewhat superior to that developed with iron oxide and can be applied to the high current-density, inert-gas-shielded arc from a steel electrode if certain precautions are taken.

Activation of Consumable Electrodes for Inert-Gas-Shielded Welding

Recent developments[1] with atomic-film cathode emission have made it possible to modify the straight-polarity inert-gas-shielded arcs of almost all electrodes to the point of matching the reverse-polarity conditions. Complete alternating-current stability can also be achieved by the same mechanism. These effects can be much stronger than is possible with oxide emission, but, more important, they make it possible to activate the nonferrous materials as well as the ferrous without producing a slag or oxide inclusions, or changing the inert character of the shielding gas. The metals which perform this activation are members of the alkali, alkaline earth and rare earth families. Their main function toward this improvement in stability is that of reducing the electrode work function. The amounts required to perform the activation cannot be observed visually, and, at times, cannot be detected spectrographically.

The major deficiency of alternating-current welding with bare electrodes has been shown to be instability with low open-circuit-voltage power supplies because of the glow discharge which is required to trigger each half cycle of current flow. This discharge requires a high voltage, and, if established, produces the spike previously illustrated in Fig. 4. A high-voltage, low-current discharge is not required if an adequate source of electrons, or ionized particles, can be maintained to initiate the arc at the beginning of each half cycle without recourse to a glow discharge. Even though the plasma is able to deionize immediately as the arc current drops below some critical value, the low work function materials can easily re-establish an arc because of the thermal lag at both electrodes. This lag in the decay of temperature permits a continued emission of electrons from surfaces with low work functions when the electrode voltage is restored. The surfaces become enveloped within a dense electron cloud, and, when the voltage rises beyond some critical value, the electrons are accelerated to the anode, energizing the plasma en route. An atomic-film cathode of rubidium, cesium, potassium, calcium, barium, strontium, lanthanum or other elements will improve the emissivity of these surfaces sufficiently to reduce the glow discharge spikes below the level for good low-voltage ignition; actually, the peaks are completely removed in most applications. The oscillograms of Fig. 10 illustrate the glow discharge spikes which develop during alternating-current welding with bare mild steel electrodes and the instability which is produced with a conventional welding transformer. The complete elimination of these peaks by activation with 0.005 weight per cent rubidium is also shown. Activation for alternating-current welding does not require the development of a high degree of stability during the straight-polarity cycle, since all the metal transfer can be accomplished during the reverse-polarity cycle.

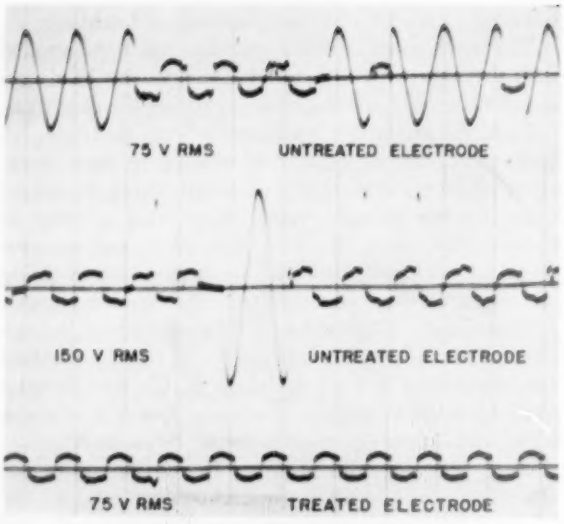


Fig. 10 Arc-voltage characteristics of untreated and activated mild-steel electrodes for alternating-current welding—argon, $^{1}/_{16}$-in.-diam electrode, 350 amp rms.

As more of the activating material is added to the electrode surface, a higher partial pressure of activating metal is produced in the plasma, and more remains on the almost boiling electrode so that a more completely covered surface is produced. This improved surface develops a lower work function as illustrated in Fig. 7, and causes an increase in the thermionic activity of the cathode. It is virtually impossible to measure the work functions of these superheated, very-short-lived surfaces, but there is ample evidence of their existence. Probably the best illustration of the effect of the lowering work function is the change in the straight-polarity melting rate which is shown in Fig. 11. These curves for cesium-activated aluminum and rubidium-activated steel show a reduction in the melting rates of the electrodes as they become more completely activated. Ultimately, an optimum surface is established for the specific operating temperature beyond which only a negligible improvement in activation is possible. The

change in the melting rate of aluminum is greater than that of steel primarily because of the lower operating temperature of the aluminum electrode. This lower temperature permits a more completely activated surface to develop.

With the increase in surface emissivity, a reduction would be expected in the area of the cathode and the ratio of positive ions to electrons within the plasma. Although no measurement of the latter is possible, the former can be observed, but only after some critical activation for thermionic emission is exceeded. The straight-polarity arc with an untreated electrode was illustrated in Fig. 3; this arc is maintained by mechanisms other than thermionic emission and can be considered a cold-cathode arc. As stated before, the iron oxide activated electrode is thermionic to a degree; a long, tapered region of electrode excitation is developed. The strongest effect possible with iron oxide, shown in Fig. 9, is equivalent to the effect developed with 0.003% rubidium. Rubidium, however, does not develop the oxide type of coating which forms with oxygen additions to the shielding gas. Figure 10 illustrates an initial increase in melting rate as low concentrations of rubidium are added to mild steel electrodes. The same peak has been found with additions to argon of 0.5 to 1% of oxygen or carbon dioxide. This increase, however, is not developed with rimmed steel because it contains residual iron oxide, and, therefore, is activated in its original condition.

The length of the taper can be reduced and the material transfer improved if titanium oxide is used in the place of iron oxide; a wash of the titanium dioxide is equivalent to 0.005% rubidium. Further improvement of the metal transfer is obtained with an increase in rubidium to 0.008%; the arc developed is very typical of reverse-polarity welding and is shown in Fig. 12. This figure also illustrates a calcium activated straight polarity arc. The cathode has a much smaller area of activity. Activation has been shown to produce

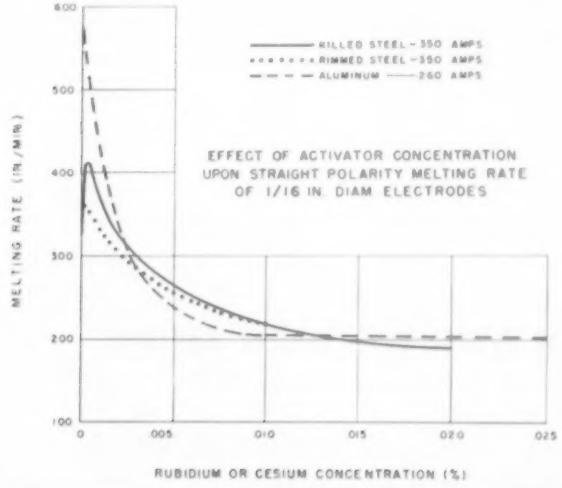
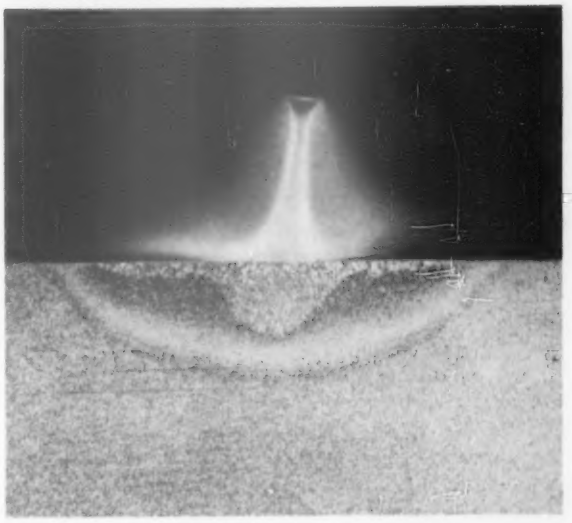


Fig. 11 Effect of rubidium and cesium in the electrode coating upon the straight-polarity melting rate of steel and aluminum electrodes

(a) Rubidium activation, 23 V, 220 ipm melting rate



(b) Calcium activation, 25 v, 220 ipm melting rate

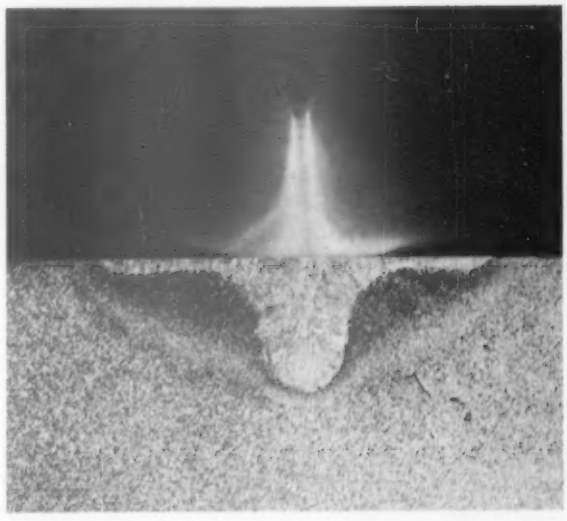


Fig. 12 Typical arcs and cross sections of welds with an activated electrode and straight polarity—argon, $^{1}/_{16}$-in.-diam mild-steel electrode, 350 amp

changes in the temperature, temperature gradient, area of excitation and amount of cation bombardment of the electrode.

These changes affect the forces which support the droplets against the acceleration of gravity and the effectiveness of the mechanism of electromagnetic pinch, and, therefore, they modify metal transfer. As the electrodes become more activated, their mode of transfer at straight polarity is improved; the metal drop size and spatter are reduced and the material movement becomes more axial. In addition, the plasma configuration changes gradually from a highly active, amorphous discharge, to one which assumes not only the stability of reverse polarity but almost its exact geometry, including the inner vapor jet. This, then, modifies the

characteristics of weld penetration; a gradual constriction and deepening of the lower portions of the weld produces the papilla which is so typical of the reverse-polarity process.

With increased activation, it is possible to reduce the melting rate of straight polarity to a value considerably below that of reverse polarity. These arcs may not be quite as stiff as those of reverse polarity, but experiments show them to have a more deeply penetrating papillary cross section.

Expected Uses of Activated Electrodes

The activation techniques are expected to increase the versatility of the inert-gas-shielded consumable-electrode process. Some of the materials may be useful to improve only reverse-polarity welding. Other agents will permit the use of techniques which were previously impossible. Spatter-free welding with conventional welding transformers is seen to be one of the most important advantages of electrode activation. As a result of this development, it is possible to reduce equipment, maintenance and power costs. The deposits are well shaped and have desirable penetration characteristics. The treatments can be designed to increase the melting rate beyond that possible with the reverse-polarity process. Possibly more important for many ferrous applications is the reduced arc blow of alternating current. It is also appealing for series-arc applications since both arcs are identical in every respect; melting rate, weld shape and penetration. The advantage of this equality of both arcs is obvious for overlay[17] and high deposition-rate processes.

The straight-polarity direct-current arcs provide the highest possible melting rate for any given magnitude of current. Bare electrodes with straight polarity have a melting rate almost double that of reverse polarity, albeit with poor transfer. Mild activation is advantageous for low penetration, high deposition-rate applications if some spatter is tolerable. A further improvement in material transfer and arc stability is obtained at the expense of a reduced electrode melting rate; ultimately, conventional reverse-polarity characteristics may be developed at straight polarity. This similarity makes series-arc processes with direct currents more practicable.

The straight-polarity arcs do not produce undercut deposits in fillets or deep groove joints. The undercut of reverse polarity may be tempered with oxygen additions if the oxygen can be tolerated by the metal or alloy being welded. Activation of the electrode is equivalent to or better than oxygen additions for minimizing undercut, and has the advantage in that it does not affect a removal of the readily oxidizable elements. These arcs are generally more stable and produce a more uniform deposit which may have less porosity. Overly activated electrodes may be used to produce deposits having restricted heat-affected zones or weld metal widths.

Activated electrodes are not expected to displace the bare electrodes now being used with reverse-polarity direct current. Rather, they are expected to increase the usefulness of the inert-gas-shielded consumable-electrode process for alternating-current welding and for those specialized applications which require controlled modifications of the present bare-electrode process.

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References

1. Muller, A., U. S. Pats. 2,694,763 and 2,694,764, Nov. 16, 1954.
2. Muller, A., and Greene, W. J., *Electric Arc and Resistance Welding*, AIEE, 61 (1954).
3. Muller, A., Gibson, J. G., and Andersen, N. E., U. S. Pat. 2,504,868, April 18, 1950.
4. Schottky, W., *Z. Physik*, **14**, 63 (1923).
5. Richardson, O. W., *Phil. Trans. Roy. Soc.*, **201**, 497 (1903).
6. Dushman, S., *Phys. Rev.*, **21**, 623 (1923).
7. Langmuir, I., and Rogers, W., *Ibid.*, **4**, 544 (1914).
8. Langmuir, I., and Kingdon, K. H., *Science*, **57**, 58 (1923).
9. Becker, J. A., *Phys. Rev.*, **28**, 341 (1926).
10. Wagener, S., and Herrmann, G., *The Oxide Coated Cathode*, Vol. II, Chapman Hall Ltd., London, p. 57 (1951).
11. Wehnelt, A., *Ann. Physik*, **14**, 425 (1904).
12. Wagner, C., and Schottky, W., *Z. Physik Chem.*, **13**, 163 (1930).
13. Wagener, S., and Herrmann, G., *op. cit.*, 150.
14. *Ibid.*, 240.
15. Cobine, J. D., and Gallagher, C. J., Am. Inst. Elec. Engrs. Tech. Paper, 51-143.
16. Conant, G. A., U. S. Pat. 2,695,945, March 30, 1954.
17. Folmley, C. R., THE WELDING JOURNAL, **34**, (6), 542 (1955).

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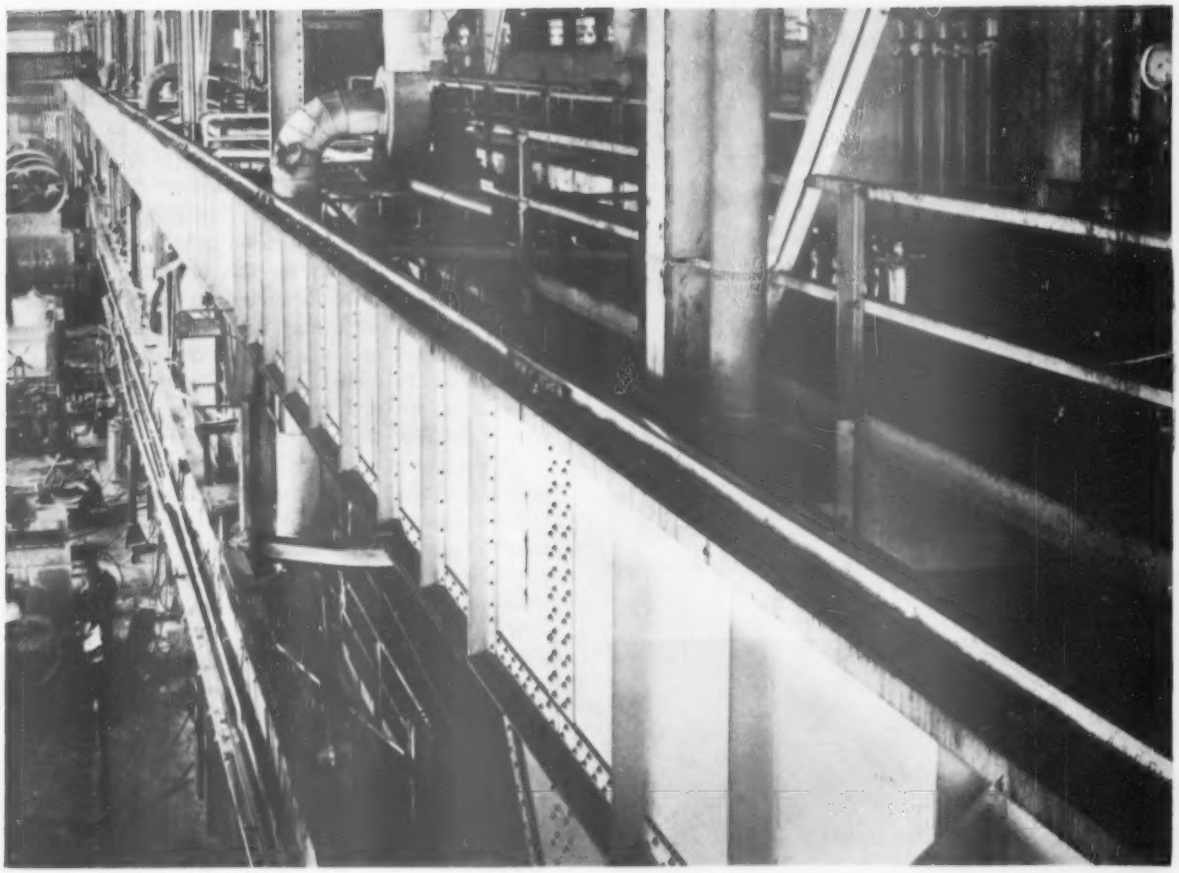


Fig. 1 A general view of an overhead crane rail in the shop of a fabricator of large pressure vessels

MANUAL-ARC WELDING OF BUTT JOINTS IN CRANE RAILS

Needless wear and deformation at crane rail ends prevented by butt welding them together with covered metal-arc electrodes

BY IVAN KUTUCHIEF

ABSTRACT. The wear and deformation on the ends of crane rails has been a constant problem, especially in shops where heavy loads are transported on large overhead cranes. A welding procedure, using special, but inexpensive, electrodes was developed to butt weld the crane rails so that a smooth and continuous track is formed. The welded joint is so constructed that wearing and pounding at the weld area are eliminated, thus providing trouble-free crane service. The welding procedure can be applied on inside as well as on outside crane installations with the ordinary precautions usually followed with metal-arc covered electrodes. In order that a satisfactory butt joint will be obtained, it is necessary that the component parts be systematically prepared for welding. The splice plates are flame cut, or beveled, so as to provide suitable contact with the rail webs and flange for making the initial fillet welds. The rail ends are then preheated and the groove is flame cut to approximately $1^3/_4$ in. in depth and 1 in. wide. After cleaning the flame-cut surfaces, the splice plates are reassembled for welding of the joint. The joint is locally preheated to 350° F and the splice plates welded, using $^5/_{16}$-in. diam AWS E6016 electrodes. The main groove is then completed using AWS E6016 electrodes for the major portion of the weld, while the last $^1/_4$ in. in depth of the groove is completed with $^5/_{16}$ in. diam AWS E15016 electrodes. This type of welded joint remained in excellent condition after continuous service for eight years.

Ivan Kutuchief is Senior Welding Engineer, A. O. Smith Corp., Milwaukee, Wis.

Presented at AWS 1955 National Fall Meeting held in Philadelphia, Pa., Oct. 17–21, 1955.

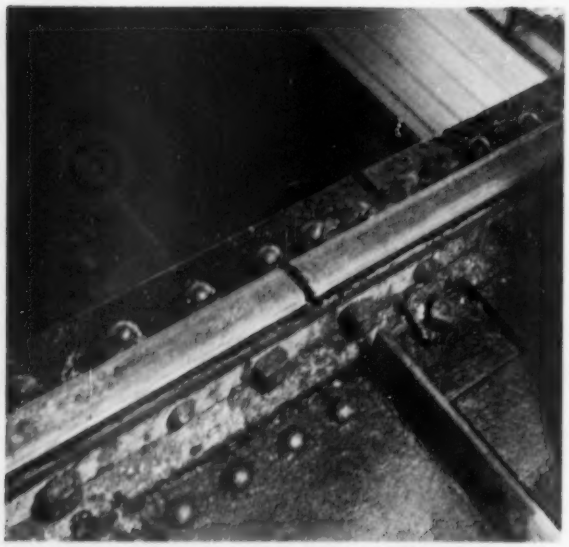


Fig. 2 Closeup of a typical crane rail joint before welding. Note the gap between the rail ends

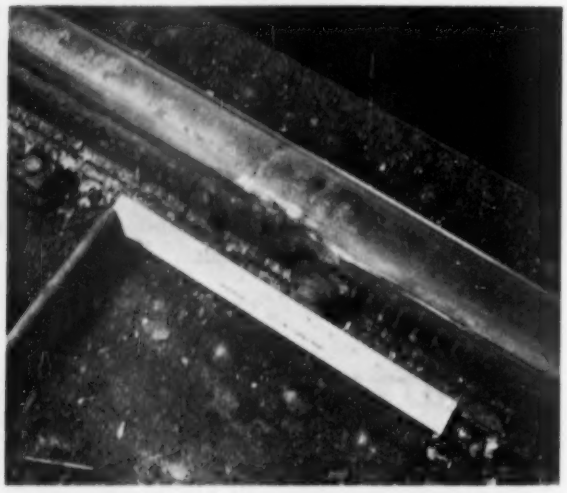


Fig. 3 Same joint as shown in Fig. 2, welded and after six years of service

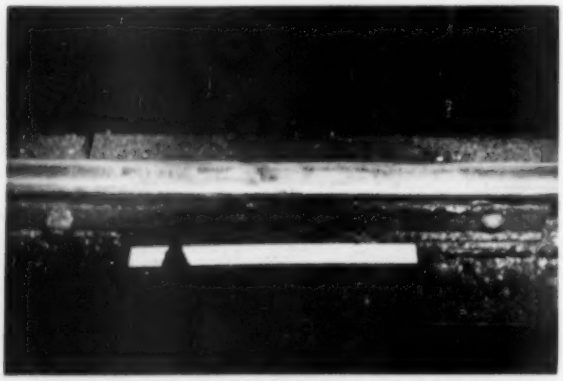


Fig. 4 Another example of a similar joint on a 300-ft long continuous crane rail track, after six years of service. There were 10 welded joints on each side of this track

Introduction

A satisfactory welding procedure has been developed for butt welding of crane rails, which procedure has been in use at various plants throughout the country. It is significant to note that so far there have been no reports of failures. This welding procedure is very practical because it can be used on existing crane rails without dismantling the rails, and furthermore it can be used on inside as well as on outside crane installations by merely following the ordinary precautions usually recommended for metal-arc covered electrodes.

The wear and deformation on the ends of overhead crane rails have been a serious problem to maintenance departments in industry, especially where large capacity cranes are used to move heavy loads from one area of the shop to another.

To counteract this potential and costly enemy, it was only logical to devise methods which would prevent the needless wear at the crane rail ends. Through considerable research, a suitable and practical welding procedure was developed to butt weld the crane rail ends, using covered metal-arc electrodes.

What are the advantages of welded overhead crane rail ends? These may be summarized as follows:

1. To form a continuous crane rail track for smooth rolling.

Fig. 5 Closeup of one of the welded crane rail joints in an outdoor steel storage yard after 6 years of heavy tonnage service. No wear or distortion has occurred

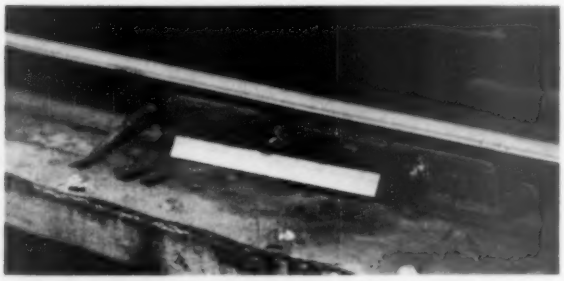


Fig. 6 Welded crane rail joint on one of the outdoor overhead cranes used for transporting large diameter pipes in storage yard. No wear or distortion has occurred after three years of service

2. To prevent preferential wearing at the crane rail ends.
3. To eliminate jarring of loaded cranes when moving over spaced rail ends (usually from 1/8 to 1/4 in. apart) especially if the rail ends are worn.
4. Maintenance problems due to low areas at worn crane rail ends are practically eliminated, thus realizing substantial savings of labor and material costs.
5. The maintenance cost of the crane equipment is likewise decreased because of the smooth travel and operation.
6. The welding with covered metal-arc electrodes is practical and economical. The joining of the crane rails can be performed without removal from the track.

One of the prerequisites in welding of crane rails is that the weld metal hardness should be similar to that of the rail steel. For example, the hardness of ordinary rail steel as used for overhead crane service may range from 320 to 340 Brinell hardness number. Accordingly, the weld metal should be of similar hardness, particularly that portion which would be subjected to wear. For this reason, the welding procedure was designed in such a way that a type of weld metal capable of withstanding the impact and wear action of rolling wheels, as normally encountered in overhead crane service, is deposited for the last three layers.

The impact resistance of the weld was determined by means of a unique cone type specimen developed by Way and Structures Committee No. 7 of the American Transit Association, as described in report of Way and Structures Committee No. 7, Proceedings of 1931, page 837.

In brief, the cone test consists of making a multilayer weld deposit approximately 1 3/4 in. in diameter and 1 1/4 in. high, then machining a cone having the dimensions shown in Fig. 14. The steps in making the cone tests are also illustrated in this same figure.

The cone is then subjected to a drop test, in which a 20-lb steel slug is dropped from a height of 5 ft. The impact of the sudden blow results in a compression or reduction of the cone height. This reduction in height is related to the inherent characteristics of certain welds to greatly resist compression, i.e., deformation under impact, such as obtained in the drop test.

The ratings of the welds subjected to drop tests is based on the number of blows required to decrease the height of the cone from the original 0.775 to 0.50 in. The height is measured at intervals of 5, 10, 25, 50 and 100 blows, when the hardness of the weld is also determined and recorded. If the weld does not decrease to 0.50 in. in height after applying 100 blows, then the test is stopped and the weld rated accordingly for its impact resistance.

The cone test is considered to be one of the reliable methods of evaluating the comparative impact deformability of different welds. It is a type of test which will show the ability of a weld deposited on rail steel to withstand the terrific rolling impact of passing car wheels. A cone, made of soft weld, will compress and widen around the base of the cone. If too hard, it may deform and crack.

A weld which will compress uniformly under many impact blows without the occurrence of cracks is the desirable type. Such a weld was developed and has been successfully used on crane rails.

The steel which is usually used for crane rail service is a straight medium carbon grade and is made by the basic open hearth process. The carbon content may range from 0.60 to 0.85%, depending on the weight per yard of rail.

Table 1 shows typical and actual chemical analyses of rail steel.

Table 1—Chemical Analyses of Rail Steel

Weight, lb. per yard	*C*	*Mn*	*P*	*S*	*Si*
50 to 60 (typical)	0.50/0.63	0.60/0.90	0.04	...	0.10/0.23
121 to 140 (typical)	0.69/0.82	0.70/1.00	0.04	...	0.10/0.23
110 (actual) (51894)	0.60	0.72	0.020	0.023	0.15

Preparation of Joints for Welding

The preparation of the crane rail ends for welding is such that only the top half of the butt joint is welded, and the splice plates on both sides. The design of the weld is such that repeated impact does not harm the weld joint as has been the experience so far.

In order to obtain a strong and satisfactory joint it is very important that the splice bars be welded to the rail flange and ball. There are various types of designs of splice bars which may require preparation for welding.

In the majority of splice bar assemblies, the edges follow the contour or shape of the rail flanges and are

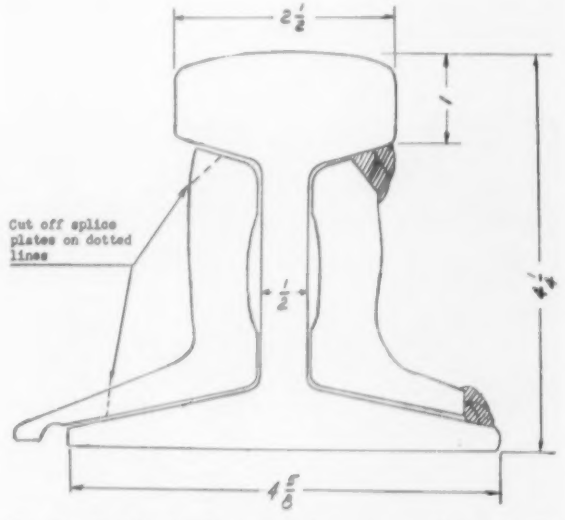


Fig. 7 Sketch showing the edge preparation of splice plates and sequence of weld deposition

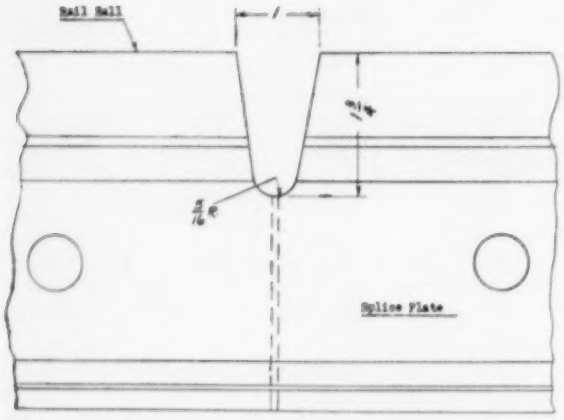


Fig. 8 Sketch showing the groove dimensions for butt welding of crane rails

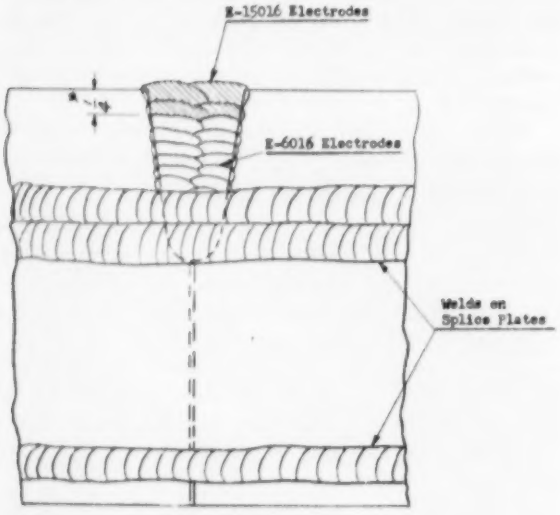

E-15016 Electrodes
E-6016 Electrodes
Welds on Splice Plates
• 1/4" depth for crane rail of 150 lbs. or less.
• 1/4" depth for crane rail heavier than 150 lbs.

Fig. 9 Sketch which shows the sequence of deposition with AWS E6016 and E15016 electrodes

bolted in place. For welding, the sides of the splice bars must be flame cut so that they can be properly fitted and assembled to the rail flange. For this operation the splice bars are removed from the rail joint and flame cut to the general edge appearance as shown in Fig. 7.

To minimize distortion due to flame cutting it is recommended that the "back-step" method of cutting be followed. This means that the cut is started in the center of the splice plate, moving toward the right end of the plate, then starting at the left end of the plate and completing the cut at the center of the plate.

Before the splice plates are reassembled, the groove between the rail ends should be flame cut to the general shape as shown in Fig. 8. All flame-cut surfaces should be properly cleaned to remove any slag and scale formed as a result of the flame-cutting operation. The cleaning may be performed with a portable electric grinder and wire brushing.

The splice plates are then assembled to the rail joint as shown in Fig. 11 making sure that good contact along the splice plates and the rail flanges has been obtained. End lugs at both sides of the groove are placed to provide suitable areas for starting and terminating the arc.

Welding Procedure

1. Electrodes

The electrodes for welding rail joints are of two grades, the AWS E6016 and AWS E15016, both of which have low hydrogen covering. The E6016 grade is used to weld the major portion of the groove, or to approximately $^1/_4$ in. from the top surface of the rail steel, while the last $^1/_4$ in. in depth of the weld is completed with the E15016 electrodes. From comparative observations it was determined that $^3/_{16}$-in. diam electrodes offered the most satisfactory performance characteristics, using 220 to 230 amp, d-c, reverse polarity on the electrodes.

The welding current should be measured with a "tong-tester" if possible. Since these electrodes are of

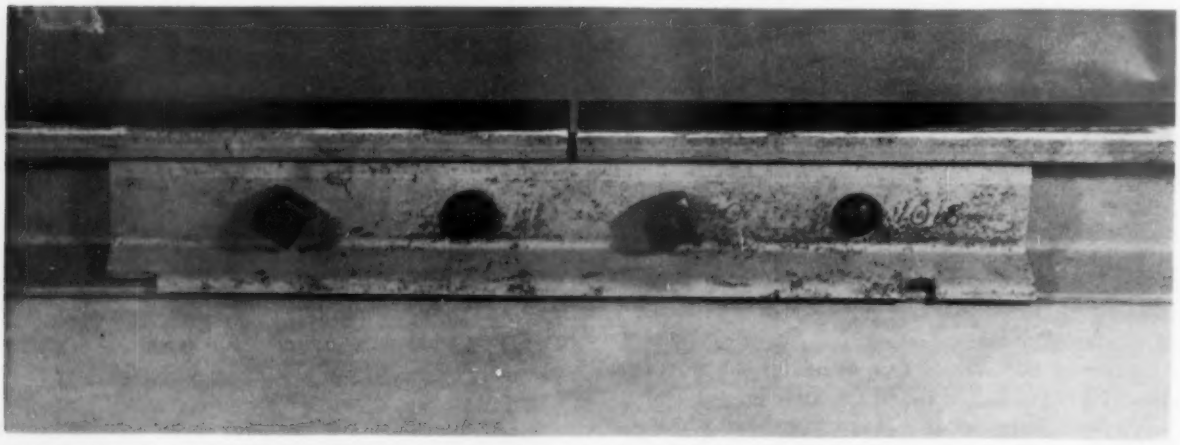


Fig. 10 Standard type of overhead crane rail joint showing the splice plates, bolts and the normal gap between the rail ends

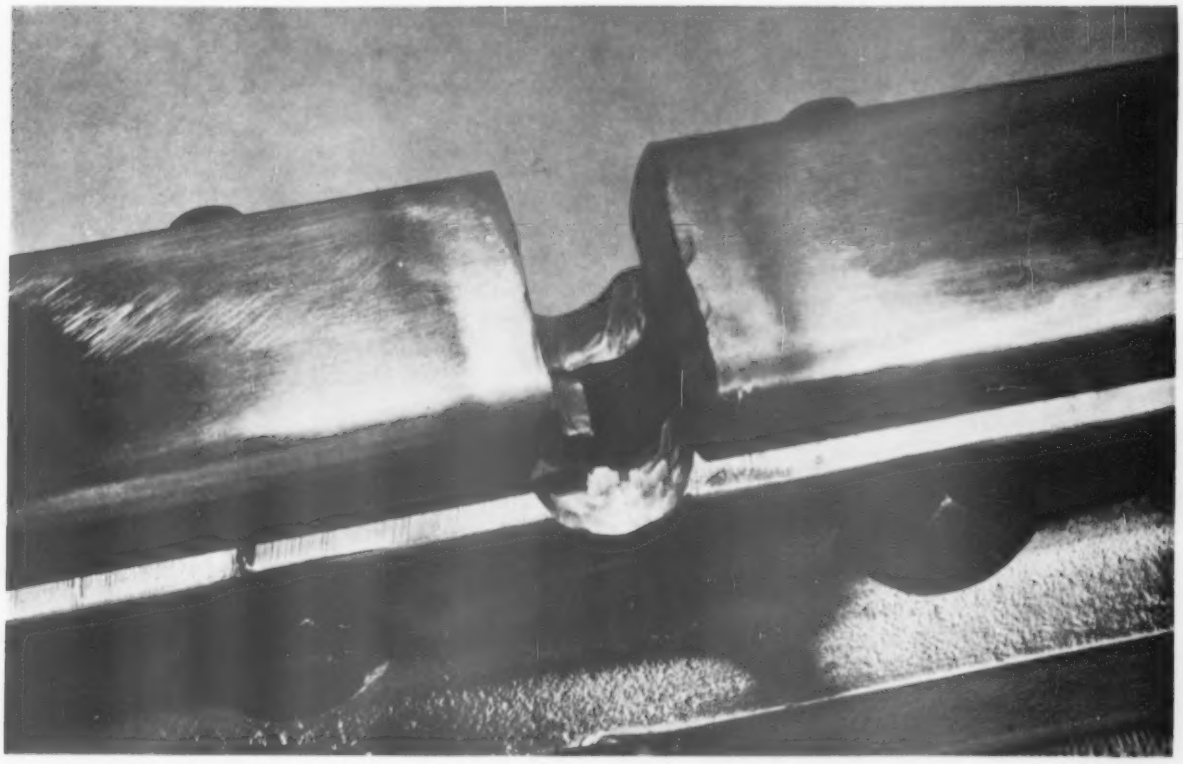


Fig. 11 Welding groove of butt joint in crane rail, showing the preparation of the parts for welding with metal-arc electrodes

the low hydrogen grade, it is important to inform the operators regarding the special starting technique necessary with such electrodes. In order to eliminate porosity at the start of the weld pass, the initiation of the arc is performed by striking the arc on the end lug follow with a "U" turn by hesitating for 1 or 2 sec and then move forward in the normal manner.

It is also important that the operator hold a short arc for porosity-free welds.

2. Preheat and Interpass Temperature

After the plates have been assembled in place, the joint should be carefully preheated with an oxy-acetylene flame to a distance of approximately 6 in. on either side, so that a temperature of 350 to 400° F is reached. The interpass temperature of the joint should be maintained within this range until all welding is completed.

3. Sequence of Deposition

(*a*) *Welding of Splice Plates.* The long edges of the splice plates are welded with $^{3}/_{16}$-in. diam E6016 electrodes, making three horizontal fillet welds as shown in Fig. 7. To minimize distortion due to the welding stresses, the "back-step" method of welding is followed. This means, that the fillet weld is started at the center of the splice plate, moving toward the right end of the joint, then resuming the welding at the left end of the splice plate, and completing the weld at the center. The deposition of the fillet welds should also be alternated from side to side. All slag on the welds must be removed prior to deposition on subsequent passes.

(*b*) *Rail Joint Butt Weld.* With the aid of the end lugs the first pass is deposited using $^{3}/_{16}$-in. diam E6016 electrodes. It is important that the arc is initiated

Fig. 12 Over-all view of welded crane rail joint, showing the welds on the splice plates and the main butt weld

Fig. 13 Welded crane rail joint with the weld reinforcement ground and ready for regular service

and terminated on the end lugs. All slag must be cleaned and the weld surface wire brushed prior to welding of subsequent passes.

The general sequence of deposition and the approximate number of double-pass layers is shown in Fig. 9. For crane rails which weigh from 90 to 150 lb per yard, the rail joint is welded with E6016 electrodes to approximately $^1/_4$ in. from the top surface of the groove, while for crane rails, heavier than 150 lb per yard, the number of layers deposited with E6016 electrodes should not extend beyond $^3/_4$ in. from the top surface.

The last two or more layers of weld metal are completed with $^3/_{16}$-in. diam E15016 electrodes, depending on size of rail.

4. Inspection of Welds

Each pass of weld metal should be visually inspected by the operator for surface defects such as pits and undercuts. These types of defects must be removed by chipping or grinding.

5. Removal of End Lugs

After completion of the last weld passes, the end lugs are removed by flame cutting along the rail joint, taking precautions not to cut beyond the width of the rail ball.

6. Finishing of Rail Joint Surface

The weld reinforcement of the last layer should be removed by grinding while the rail steel is still hot, so that a smooth and uniform area is obtained. The welded area is then reheated with the oxy-acetylene torch to a temperature range from 350 to 450° F for approximately 12 in. on either side and should be covered with asbestos blanket to retard the cooling rate.

7. Time Evaluation of a Butt-Welded Crane Rail Joint (120 Lb Weight)

The approximate time to prepare and weld a typical crane rail joint was estimated as follows:

(*a*)	Time to dismantle the splice plates, then flame cut the edges and clean slag	45 min
(*b*)	Flame cut the joint itself	15 min
(*c*)	Assembly of splice plates and welding along edges; 3 layers of weld metal on each edge—4 edges	90 min
(*d*)	Welding of butt joint	90 min
(*e*)	Burning of end lugs and grinding of weld and roughness from sides	30 min
	Total time	270 min or 4.5 hr
	Electrodes: 10 lb at $0.25 per lb	$2.50

No expenses for oxy-acetylene gases have been included since those are usually part of overhead charges, and may vary from plant to plant.

8. Field Reports on Welded Crane Rails

The successful performance of welded crane rails has been substantiated by reports received from several industrial plants where overhead cranes are moving heavy loads in the course of manufacturing activities. Overhead crane rails at the steel mills of prominent steel makers, automobile manufacturers and fabricators of steel products are butt welded according to the above-described procedure, because the maintenance supervisors have learned from actual service analyses that smooth welded crane rails contribute toward trouble-free crane service. Examples of welded joints on crane rails, which have been in service for several years, are shown in Figs. 1 through 13.

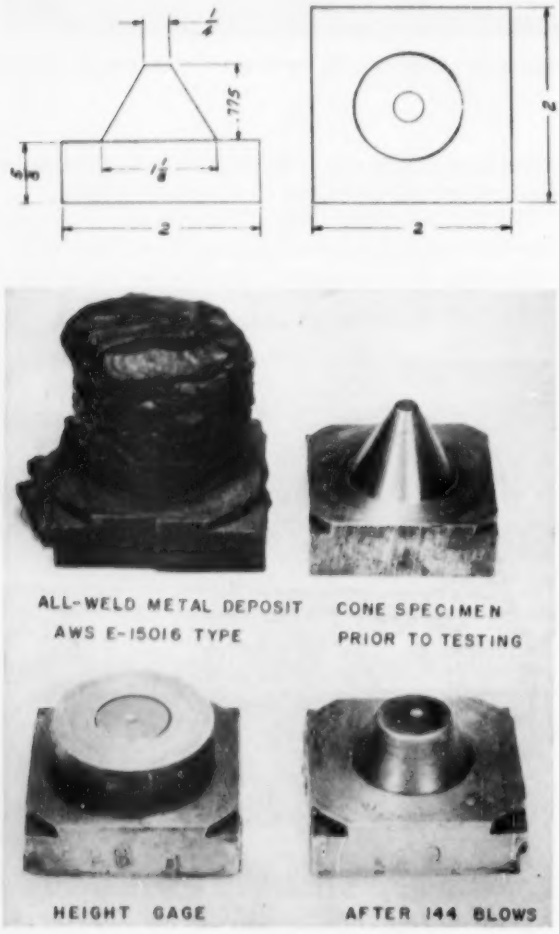


Fig. 14 Details of cone specimen and cone test

Acknowledgment

This welding procedure was developed at the Welding Research Laboratory under the direction of J. J. Chyle, Director of Welding Research, A. O. Smith Corp.

The writer appreciates the permission of A. O. Smith Corp to present this data.

Reference

1. Hibbard, F. G., "Development of Low Hydrogen Electrodes for Rail Welding," paper presented before the Way and Structures Division of the American Transit Association, Milwaukee, April 28 and 29, 1949.

Inert-gas tungsten-arc welding of piping

ENGINEERING ASPECTS OF INERT-GAS TUNGSTEN-ARC WELDING OF PIPING

Effects of joint design and purging, root-pass cracking, limitations of inspection techniques, advantages of consumable welding insert rings

BY HELMUT THIELSCH AND C. S. PULLIAM

Introduction

Many piping fabricators and erectors have in the past and are now investigating various methods designed to eliminate metal backing rings. In power piping particularly, backing rings have been and are still widely used in butt-welded joints in piping inaccessible for grinding or welding from the inside of the pipe joint. Backing rings were primarily necessary where the root pass was made by shielded metal-arc welding with covered electrodes or by automatic submerged-arc welding. The backing ring provided solid metal "backup" against which the root pass was deposited. Their primary advantage was that they helped to (1) avoid burn-through, (2) prevent weld spatter and slag drippings from falling into the pipe and (3) insure full penetration and fusion at the root of the butt weld in all positions of welding.

A typical backing ring assembly, as used in steam power piping, is illustrated in Fig. 1. The fact that many hundreds of thousands of pipe joints made with backing rings have not given any trouble proves this to be a completely satisfactory method of pipe welding. Extensive investigations of service failures or near failures in piping systems have shown that the very great majority have occurred in joints made by shielded metal-arc welding without backing rings where lack of penetration resulted in notches of significant severity.

Helmut Thielsch is Metallurgical Engineer and **C. S. Pulliam** is Research Engineer, Grinnell Co., Inc., Providence, R. I.

Presented at 1955 AWS National Spring Meeting held in Kansas City, Mo., June 7–10, 1955.

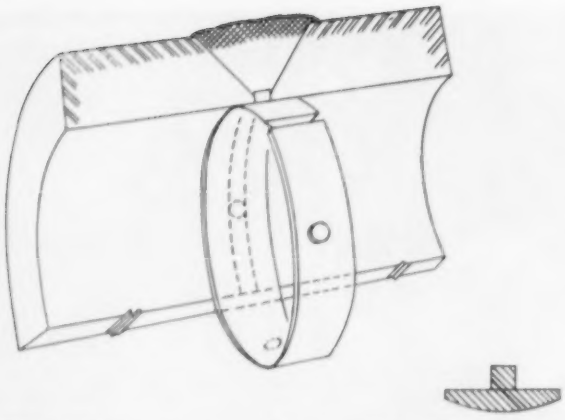


Fig. 1 Backing ring assembly commonly used in steam power piping

The notch was continued into a crack and propagated by mechanical or thermal fatigue, stress corrosion, caustic embrittlement or stress rupture. An example of a stress-corrosion crack in a carbon steel pipe joint originating at the root of the weld where lack of penetration was present is shown in Fig. 2. The extremely few isolated cases where failure has occurred in welds made with backing rings can be related almost always to improper welding, particularly where the root penetration was incomplete or fit-up was unsatisfactory. If such improperly made welds had been observed in the initial radiographs and repairs had been made, failure might have been avoided altogether.

In a few instances cracking in service has been due also to the use of welding electrodes of improper composition.

In spite of the fact that no significant trouble has been encountered with conventional backing rings, their elimination is nevertheless desirable. For example, accurate fit-up is important with backing rings to avoid the formation of cracks in the root pass originating where the backing ring-to-pipe contact area meets the weld fusion zone. A root crack originating at a notch formed by improper fit-up is illustrated in Fig. 3. Actually such undesirable root conditions are extremely rare. Since they can usually be noted on radiographs, such conditions are repaired by a responsible pipe fabricator.

Power Piping

In power piping, until a few years ago, the use of backing rings was almost always specified. Only in a few isolated cases have special types of joints been welded in which backing rings have been eliminated. A typical example is illustrated in Fig. 4. After a few installations these methods have generally been discarded in favor of the more conventional backing ring methods. Unless properly fused they tended to leave dangerous notches in the root pass transverse to the pipe wall thickness which, in several cases, have been propagated into cracks traversing the pipe weld.

Process Piping

In process piping in refineries and chemical plants, backing rings have been employed in pipe and tube welding in only a relatively few cases. The lighter wall thickness of the pipe used, as compared to power piping, the importance of eliminating local build-up of corrosive sludges and the necessity for periodic cleaning with scraping tools made a smooth internal pipe contour very desirable. Therefore, the weld usually has been made by shielded metal-arc welding without backing rings. Nevertheless, such welds are likely to contain lack of penetration and, in time, they may fail if the service conditions are sufficiently critical.

Inert-Gas Tungsten-Arc Welding

In the inert-gas tungsten-arc welding process an arc is struck between the work and a single, usually thoriated, tungsten electrode. During welding, argon or helium gas is flowed around the electrode and over the weld metal pool to avoid contamination by the atmosphere and assist in the ionization of the arc.

The inert-gas tungsten-arc welding process has been used commercially since approximately 1940. Inert-gas tungsten-arc welding was first used on thin-walled piping and tubing, primarily the Schedule 5 and Schedule 10 stainless steel piping employed in the chemical industry, a few years after the end of the second world war. It is only now that this process is becoming accepted for the so-called root-pass welding of heavy piping.

Fig. 2 Stress-corrosion crack in carbon steel pipe joint at notch formed by incomplete penetration

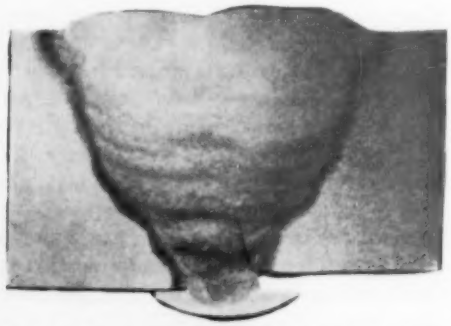


Fig. 3 Root crack at notch formed by improper fit-up of backing ring

On pipe and tube joints of wall thickness up to 1/4 in. thick the entire weld is made by the inert-gas tungsten-arc welding process. On piping and tubing of heavier wall thickness usually only the root pass is made by the inert-gas tungsten-arc process and the balance of the weld is made by manual metal-arc welding with covered electrodes or, in some cases, by automatic submerged-arc welding or by automatic inert-gas consumable-electrode metal-arc welding, the conditions varying somewhat with the materials to be welded, the pipe wall thickness and the welding conditions existing at the particular shop or field erecting site.

The first applications of the inert-gas tungsten-arc process were in the welding of stainless steel pipe and tube materials. In recent years, however, increasing use has been made of this process in the welding of low-alloy (usually chromium-molybdenum) and carbon steel tubing and piping.

Joint Designs

Various joint designs have been used and recommended for inert-gas tungsten-arc welding of pipe and tubing materials. The more common types are illustrated in Fig. 5.

For pipe and tube wall thickness up to 5/32-in. square butt-type joints are usually employed without a root opening or "V"-groove preparation. Between 5/32 and 3/8 in. a "V"-groove preparation is preferred with a 1/16-in. root face and without root opening. On heavier wall thicknesses "U" and special so-called "flat-land" "V" bevels are generally employed with a 1/16- and 3/32-in. root face, respectively, and without root opening.

Since standard fittings of wall thickness 3/4 in. or less are furnished with a 37 1/2° "V" bevel, pipe-to-fitting joints are often welded with different combinations of joint preparations.

The "U" and the special "V" bevel preparation with the "flat-land" are more costly to machine than the straight "V" bevel. However, the "U" and "flat-land" bevels allow better tungsten electrode manipulation and more rapid electrode travel. They reduce susceptibility to cracking in the root deposit and provide more uniform root penetration. Greater welder skill also is required for welding in the conventional "V" bevel than for the other two types of groove preparation.

Commercial Pipe and Tubing Materials

Extensive laboratory and shop fabrication experience has shown that the initial enthusiasm displayed for the inert-gas tungsten-arc root-pass welding process was somewhat premature. Sections removed from commercially made pipe welds have revealed the presence of fine root cracks which, in some cases, have been further extended during service. These cracks were not detected by conventional radiographic inspection techniques and, consequently, were not removed prior to placing the piping system into service. Their presence, therefore, represents potential danger points to the system. Under service conditions of mechanical or thermal fatigue or shock, stress corrosion or caustic embrittlement these small cracks may be propagated and ultimately lead to a failure across the joint.

The best insurance against the presence of fine root cracks and for proper complete root penetration is to use thoroughly trained and experienced welders and rigid inspection techniques. This naturally favors shop fabrication over field fabrication. Consequently, prefabricated assemblies made under shop conditions should be employed wherever possible.

The various factors which influence cracking in the root pass or produce other undesirable conditions are evaluated in the subsequent discussion. Since commercial carbon and chromium-molybdenum alloy steel piping, 4 in. and larger, has a wall thickness of over 1/4 in., the inert-gas tungsten-arc process is primarily used on the root pass, subsequent passes generally being made by shielded metal-arc welding. On the other hand, stainless steel pipe and tubing, even of larger

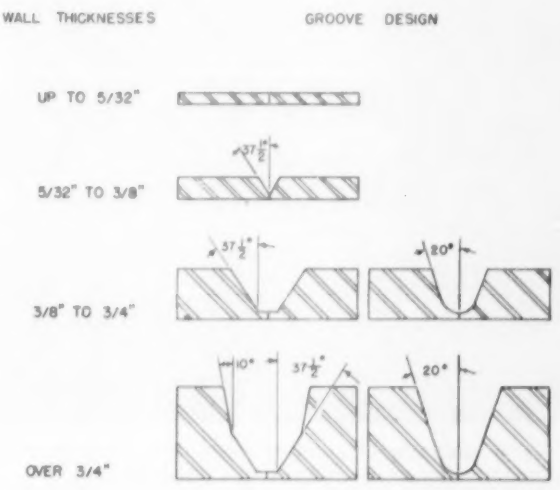


Fig. 5 Sketch of joint designs commonly used for the inert-gas welding of piping materials

diameters, are used in relatively thin wall thicknesses (for example, 8-in. diam, Schedule 5 pipe has a wall thickness of only 0.109 in.) as well as in medium to heavy wall thicknesses (8-in. Schedule 80 pipe has a wall thickness of 1/2 in.).

Thus, whereas the so-called root-pass welding procedure applies to carbon, chromium-molybdenum and stainless steel pipe, the welding of a complete joint by the inert-gas tungsten-arc process essentially is applied only to the thin-wall stainless steels mentioned above.

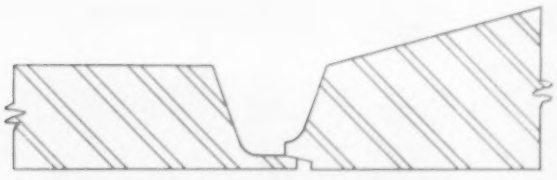


Fig. 4 Example of special pipe joint design to eliminate backing rings

This paper has been prepared in accordance with these considerations.

Welding Variables

Use of Filler Wire in Root Pass

Manipulation of the tungsten electrode holder is easiest if the initial "root" pass is made without filler metal. The resulting better control of the weld puddle also insures more uniform root penetration and is less likely to cause burn-through. On the other hand, the use of filler metal is often beneficial in avoiding cracking in many alloy steels susceptible to crater cracking as, for example, in root-pass welds in the Type 347 stainless steel grade.

Tack Welding

Tack welding is usually advisable to insure proper pipe alignment and minimize distortion during welding of the root pass. Good practice is to deposit two $^1/_8$- to $^1/_4$-in. tack welds in pipe up to 4 in. diam. In pipe over 5 in. in diam and over the tack welds should be made at 4- to 6-in. intervals. The tack welds should be fused through the full thickness of the land. The electrode should be manipulated slowly toward the side of the groove before the arc is broken. A properly made tack weld is illustrated in Fig. 6.

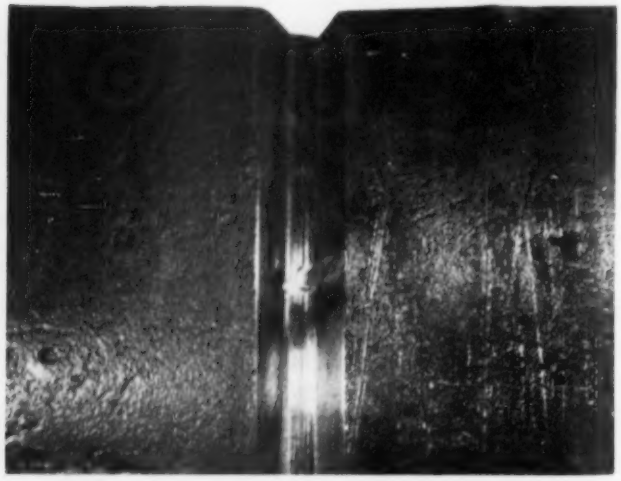


Fig. 6 Example of properly made tack weld in $2^1/_4$ Cr–1Mo alloy steel. Filler metal was not used

Root-Pass Cracking

One of the major problems in inert-gas root-pass welding is the formation of fine crater cracks and, to a lesser extent, centerline cracks.

Crater cracks occur at the locations where the welder breaks the arc as illustrated in the radiographs shown in Fig. 7 of root-pass welds in $2^1/_4$Cr – 1Mo alloy steel and Type 347 (18Cr – 8Ni-Cb) stainless steel. In most cases the crater cracks extend through the whole section thickness of the fused root-pass metal. This is illustrated in Fig. 8 showing a crack traversing the whole cross section of a root-pass weld but not penetrating the subsequent bead deposited by metal-arc welding.

Centerline cracks, though often similar to crater cracks, frequently are longer than crater cracks. They may occur in carbon, alloy and stainless steel welds and are usually caused when high stresses as produced by shrinkage cause a "tearing apart" of the center of the root-pass weld. Typical centerline cracks in $2^1/_4$Cr – 1Mo and in Type 347 stainless steel root-pass welds are shown in Fig. 9.

Joint design influences the tendency toward crater and centerline cracking. As a general rule, pipe joints with a "V" bevel preparation are more susceptible to cracking in the root pass than joints with "U" or "flat-land" end preparations.

This crack formation is not always appreciated. Most welding specifications for heavy-wall high-temperature power-plant piping require radiographic examination of the joint only after the weld has been completed. The fine root-pass crater cracks usually will not show up in X-ray radiographs of pipe with wall thickness of $^1/_2$ in. or heavier. Gamma-ray or radioactive cobalt exposures are even less sensitive.

The "disappearance" of root-pass cracks with weld metal build-up in a $1^1/_4$Cr – $^1/_2$Mo steel is illustrated in the series of X-ray radiographs shown in Fig. 10. The root pass was made by inert-gas tungsten-arc welding without the addition of filler metal. All subsequent passes were made with Type E8016 covered electrodes. The root-pass cracks were still visible by X-ray radiography after deposition of the first "cover" pass with the E8016 electrodes. They were not propagated into this pass. Detection of the crack is difficult after the

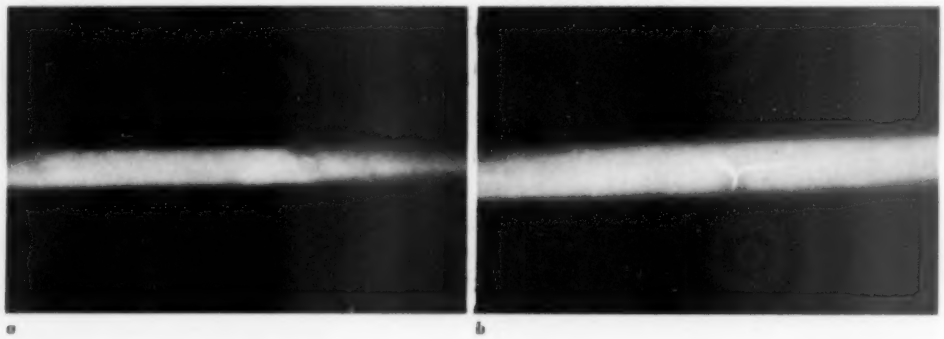
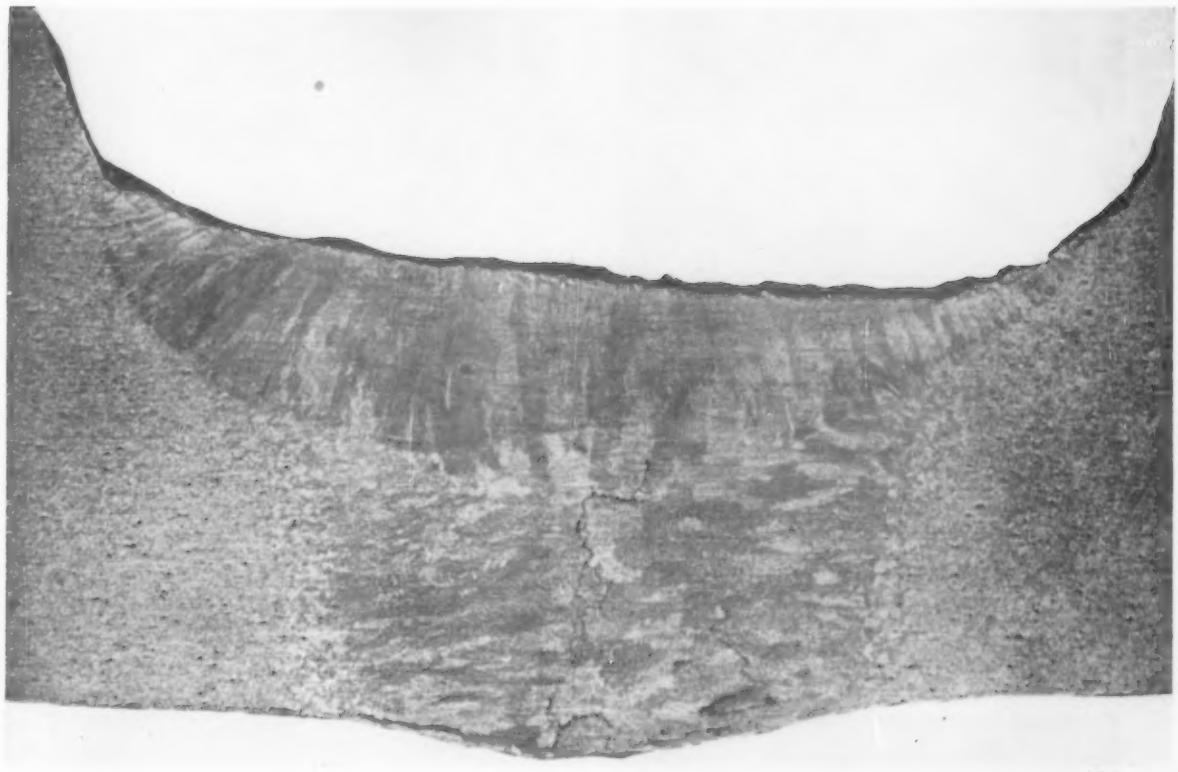
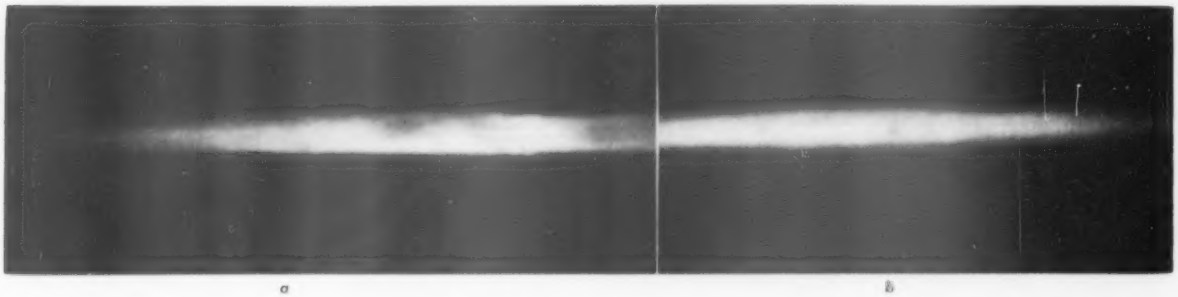


Fig. 7 X-ray radiographs of crater cracks in (*a*) $2^1/_4$Cr–1 Mo and (*b*) Type 347 stainless steel root-pass welds



X16

Fig. 8 Cross section of two-pass weld containing crater crack in Type 347 stainless-steel root pass, but not penetrating the subsequent metal-arc pass. (Reduced by 25% upon reproduction)



a b

Fig. 9 X-ray radiographs of centerline cracks in (a) 2¼Cr – 1Mo and (b) Type 347 stainless steel root-pass welds

second E8016 pass, and after the third E8016 pass they were no longer visible. A photograph of the etched cross section illustrating the extent of crack is shown in Fig. 11. As pointed out earlier such cracks represent severe stress raisers which, in time, may propagate across the joint.

Long centerline cracks also may not appear on X-ray radiographs after the first metal-arc covered electrode pass is deposited over the root pass because the shrinkage of this weld pass may draw together tightly the crack in the root pass. Certainly, the potential danger of such cracks has not been lessened by their being closed up mechanically.

Small crater cracks of the types shown in Figs. 7 and 8 also may not be detected in radiographs made after deposition of the first metal-arc covered electrode pass.

The presence of the fine root-pass crater and centerline cracks cannot always be observed by careful visual examination of the inert-gas tungsten-arc root pass. The welder, therefore, may not be aware of their presence. Since the chromium-molybdenum alloy steels generally require a continuous preheat until several layers of weld metal* have been deposited, detection of

* Pipe Fabrication Institute, Standard ES (M) 8-1955 states that "Welding on 1Cr – ½Mo and 1¼Cr – ½Mo materials may be interrupted at any time provided that a minimum of at least ⅛ in. thickness of weld deposit or 25% of the welding groove is filled (whichever is greater)." On 2¼Cr – 1Mo 3Cr – 1Mo and 5Cr – ½Mo welding may not be interrupted unless partial or complete stress relief is given.

The American Welding Society Committee on Piping and Tubing states in their forthcoming "Recommended Practices for Interruption of Heat Treatment Cycles for Low Chromium-Molybdenum Steel Piping Materials" that on all of these steels preheat should in no case be interrupted before one-third of the wall thickness or two layers of weld metal (whichever is greater) are deposited.

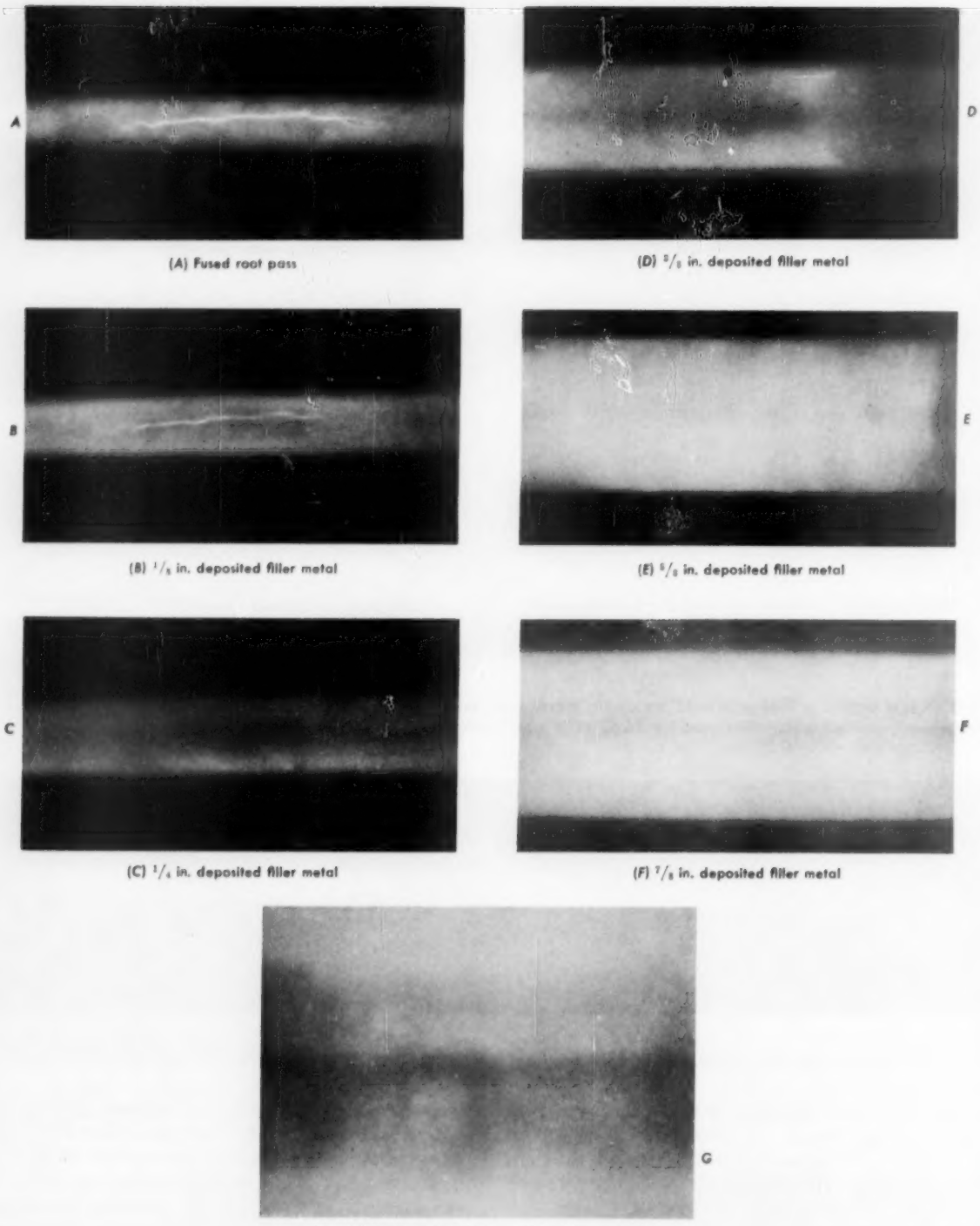


Fig. 10 Series of X-ray radiographs illustrating the "disappearance" of a centerline crack with increasing weld-metal thickness in $2^1/_4$Cr – 1Mo alloy steel

cracks in the root pass of preheated piping may not be possible. The preheat requirement on the chromium-molybdenum steels of 400 to 500° F eliminates the dye-penetrant inspection methods. Thus the only remaining techniques showing promise on chromium-molybdenum alloy steel piping are magnetic particle inspection and special radiographic procedures employing radium or radioactive isotopes. Both of these are now

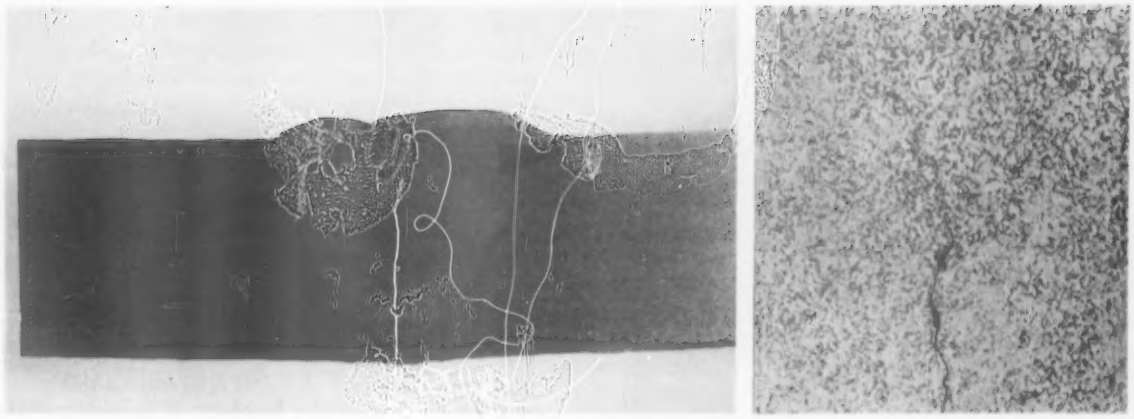


Fig. 11 Photograph of etched cross section of weld from Fig. 10 showing presence of crack in root pass

being evaluated. Conventional magnetic particle techniques frequently have failed to detect some of the fine root-pass cracks which do not extend visibly to the surface of the welds.

In the meantime, the safest practice is to use highly experienced welders and follow welding procedures which minimize the tendency for root-pass cracking and to have the inert-gas root pass inspected carefully by a qualified inspector or responsible welding supervisor. On piping of diameters exceeding 6 in., radiographs made after welding $^1/_4$ in. of the pipe wall thickness may provide additional insurance by detecting the larger of the root-pass cracks.

Proper repair of the fine root-pass cracks should be done by very careful grinding and repair welding—usually with the addition of filler metal.

Depending upon the materials welded, root-pass cracking may be minimized by (1) "U" or "flat-land" groove preparation, (2) addition of filler metal, (3) use of consumable insert rings, (4) drawing tungsten electrode back over weld by $^1/_4$ in. before breaking arc, (5) drawing electrode sidewards over bevel before breaking arc or (6) supplying filler metal before breaking arc. Most important, however, is welder training and experience which favors shop fabrication over field fabrication, particularly since proper inspection is more readily accomplished under shop fabrication conditions.

Weld Metal Sag

The weight of molten weld metal causes sagging ("sink") of the root pass. In the flat position this results in a slight convexity in the weld underneath the joint and in the overhead position a slight concavity is formed. Slower welding speeds and higher amperages tend to increase the degree of sag.

In horizontal pipe welding where the pipe can be rotated or rolled so that all welding is done in the flat position the underside of the butt weld will be convex around the circumference. In horizontal (fixed) pipe welding where rolling is not possible, the underside of the weld made at the top of the pipe joint in the flat position will be convex and at the bottom of the pipe joint in the overhead position will be concave.

Methods used to minimize sag are mentioned later on in the discussion on purging and consumable rings.

Oxidation of Underside of Weld

The underside of the weld which is not significantly protected by the inert gas will be covered by an oxide film (scale) upon cooling to room temperature.

On the carbon and chromium-molybdenum alloy steels (containing up to $2^1/_4\%$ chromium) the scale formed under ordinary welding conditions is not sufficiently heavy to have any significance. In fact, where a subsequent stress-relieving heat treatment would be employed, the additional scale formed by the postheat treatment would be heavier than the welding scale. A photograph of the underside of a $1^1/_4Cr - {}^1/_2Mo$ weld is shown in Fig. 12.

Fig. 12 Appearance of underside of inert-gas tungsten-arc fused root pass made without purging on $1^1/_4Cr - {}^1/_2Mo$ pipe weld

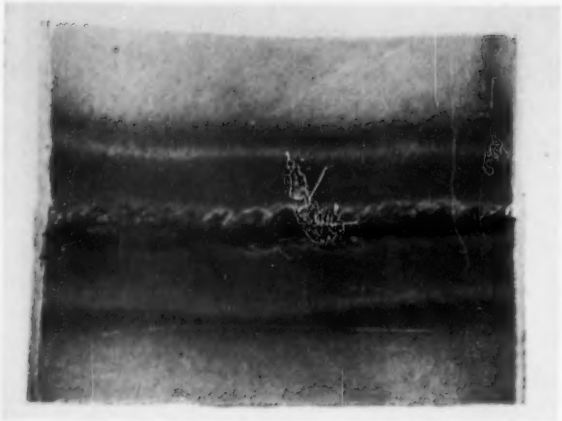


Fig. 13 Appearance of underside of pipe weld made without purging, illustrating heavily oxidized rough "cauliflower-type" formation

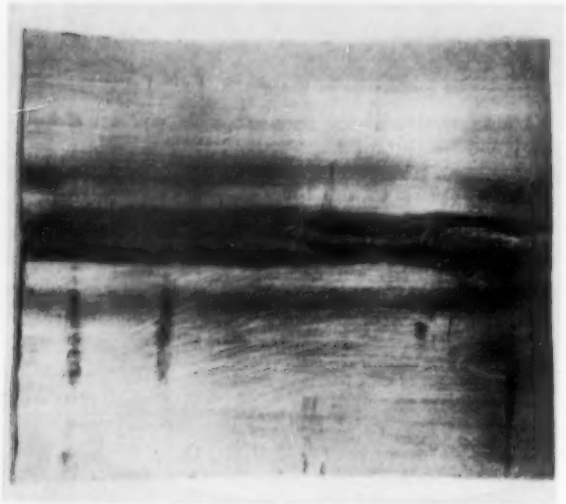


Fig. 14 Appearance of underside of pipe weld made with purging, illustrating smooth appearance of weld

Purging the underside of the joint with inert gas primarily smooths and brightens the underbead appearance of carbon and chromium-molybdenum steel root-pass welds. A slightly heavier oxide scale may form when welding with an argon-shielded tungsten-arc (no purging) where higher amperage and slower welding speeds are used for full-penetration welding than when welding with helium shielding.

On stainless steels quite a heavy scale will form on the underside of the weld. Oxidation is particularly severe on pipe and tubing of lighter wall thicknesses (Schedules 5 and 10). As illustrated in Fig. 13 the rough "cauliflower-type" formations on the underside of the weld are traversed by fine cracks which tend to protrude into the inside of the pipe, particularly at the top of the pipe where the weld has been made in the flat position. In certain chemical applications this protrusion may promote the build-up of corrosive sludge. Moreover, the over-all corrosion resistance to certain solutions of such severely oxidized areas also is considerably lower. Although grinding may eliminate the protrusion, the fine cracks often penetrate more deeply into the root of the weld and consequently reduce the effective wall thickness of the pipe.

Purging

One method widely used to avoid the excessive oxidation resulting in the rough underbead appearance consists of displacing the air underneath the joint area (root) with inert gas. The procedure generally is referred to as purging. The underside of a stainless-steel pipe weld protected by liberal purging is shown in Fig. 14.

On short lengths of pipe or tubing the open ends are usually sealed off or capped and a liberal amount of inert gas is introduced through the cap at a slightly higher pressure than atmospheric pressure to displace all of the air from the enclosed area. On tubing of considerable length, special sealing arrangements are often employed which produce an enclosed area on both sides of the weld. The purpose of this arrangement is to minimize the amount of inert gas required for purging, since its high cost adds considerably to the cost of fabrication. A typical purging arrangement is illustrated in Fig. 15 (*A* and *B*).

Purging with Positive Pressure

A number of investigators have reported that where

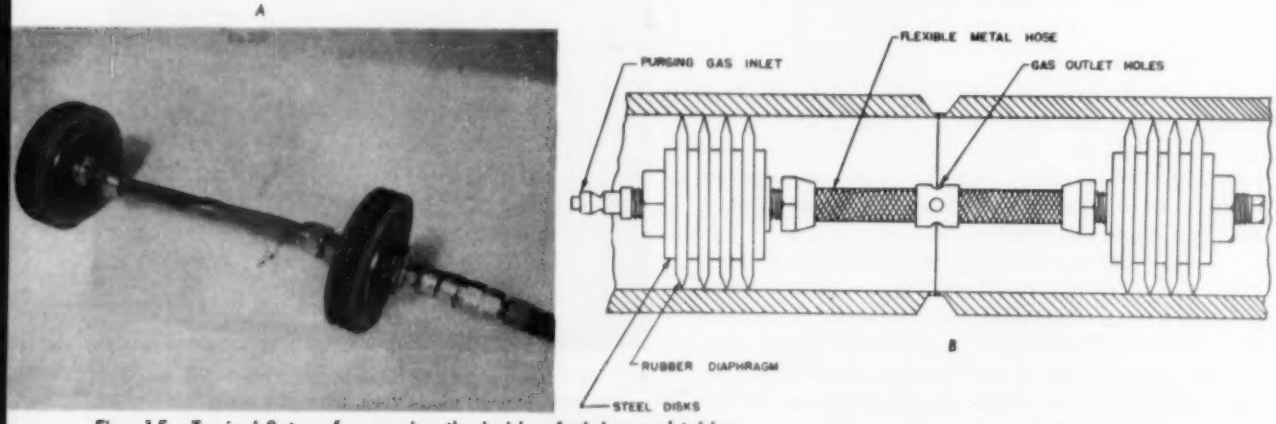


Fig. 15 Typical fixture for purging the inside of piping and tubing

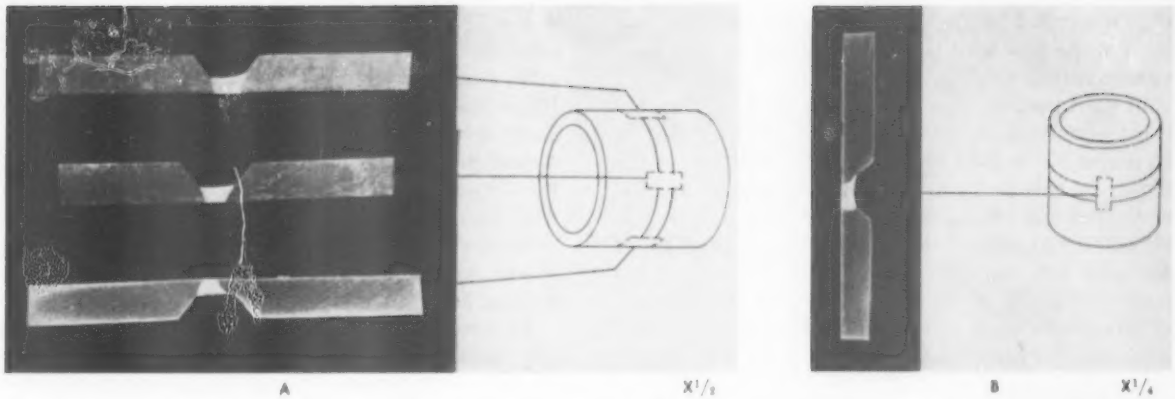


Fig. 16 Contour of root-pass welds in stainless-steel piping made with argon purging at 0.25 oz. per sq. in. pressure (A) in fixed-position horizontal pipe, and (B) in fixed-position vertical pipe.

a smooth internal root bead contour is essential the pressure of the inert gas on the inside of the pipe should be varied to compensate for the weight of the molten weld metal which tends to sag downward and results in a convex bead appearance at the flat (top) position of the pipe and a concave appearance at the overhead (bottom) position. The pressure required for protection against oxidation and "back-up" in the fixed horizontal position varies somewhat with the pipe material, the size of pipe, the dimensions of the groove design and the quality of the fit-up. The last factor may vary somewhat with the progress of the welding operation. Gas leakage through the joint may increase slightly at the start of welding as a result of a slight widening of the distance between the unwelded portion of the root faces on the opposite side of the started weld. This is primarily caused by weld shrinkage. As welding of the root is continued, the very slight gap possible between the root faces will be gradually closed and the amount of leakage will be reduced to zero.

Average conditions for root-pass welding of austenitic stainless-steel piping with argon as purging gas are represented by the following values:

Flat position (top of pipe)	1.0 oz/in.² pressure
Vertical position (side of pipe)	0.15 oz/in.² pressure
Overhead position (bottom of pipe)	0.10 oz/in.² pressure
Horizontal position (pipe vertical)	0.15 oz/in.² pressure

Thus, where a "perfect" root smoothness is desirable the so-called positive purging pressure should be increased gradually as the welder moves his torch from the vertical to the flat position. In shop and field welding this is not too practical and, indeed, is rarely used since it would require several men per weld. A pressure control varying with the position of welding is also difficult due to the fact that the amount of gas leakage through the unwelded portion of the joint will decrease as the weld gradually is being closed.

In most shop and field welding operations a varying pressure control actually is rarely necessary and a good root contour is obtained with an argon purging pressure of approximately 0.25 oz per sq in. Typical root contours obtained with a 0.25 oz per sq in. pressure for stainless-steel pipe welded in flat, vertical, overhead and horizontal positions are illustrated in Fig. 16.

Consumable Insert Welding

Consumable inserts in the form of rings or other special shapes have been used extensively in the brazing of steel parts. The inserts (or preforms) are usually made of silver- or copper-base alloys and are used with suitable fluxes. The brazing inserts are melted by heating with gas torches or burner setups or by induction or furnace heating. Since the steel base metal does not melt, the strength of the joint depends upon surface diffusion or alloying.

The adaption of the inert-gas tungsten-arc process to the root-pass welding of butt joints in piping has led to the development of a number of consumable inserts. Although of the same type of composition as the base metal, the chemistry of the inserts is usually more carefully controlled. The presence of impurities, segregations and other undesirable conditions of nonhomogeneity in the base metal may reduce the quality of the root-pass welds. For example, considerable differences have been observed in the root-pass "weldability" in carbon steel piping purchased to the same ASTM pipe specification and grade (as ASTM A-106, Grade B). Welding inserts of properly controlled composition supply additional filler metal and help to improve the ease of welding and the final quality of root-pass welds.

Most widely known so far is the so-called consumable EB insert wire which is inserted between the machined root faces, as illustrated in Fig. 17.[1] Disadvantages of this wire are the difficult fit-up and the extensive tack welding required. Its relatively high cost is another factor to consider.

In our development program a consumable insert ring similar to the above-mentioned brazing inserts was used. By means of guide pins or crimped edges in the insert

Fig. 17 Schematic sketch of "EB" insert.

ring, illustrated in Fig. 18, insertion between the root faces of the pipe ends is possible without or only with minimum tack welding.

In fixed position pipe welding the guide pins are located slightly off center. This allows the insert ring to be placed in the joint eccentric to the centerline of the pipe. In this position the ring compensates for the downward sag of the molten weld metal and avoids excessive convexity at the top ID position (Fig. 19) of the pipe and excessive concavity at the bottom ID position (Fig. 20) of the pipe. Typical groove contours of pipe welds made in the flat, vertical and overhead locations of a horizontal fixed position pipe are shown in Fig. 21*A* and in the horizontal position of a vertical fixed pipe are shown in Fig. 21*B*.

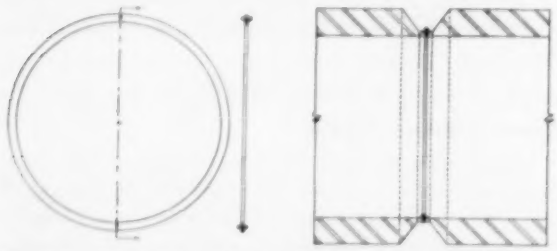
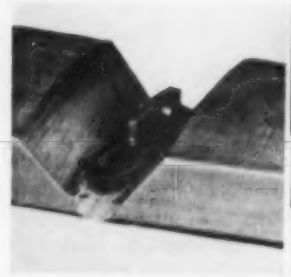


Fig. 18 Sketch of welding insert ring showing location of "guide" pins for eccentric insertion of ring in pipe joint.



X1

Fig. 19 Photograph of top of pipe section illustrating eccentric insertion of insert ring protruding into the groove.

X1

Fig. 20 Photograph of bottom of pipe section illustrating eccentric insertion of insert ring protruding into the inside of the pipe.

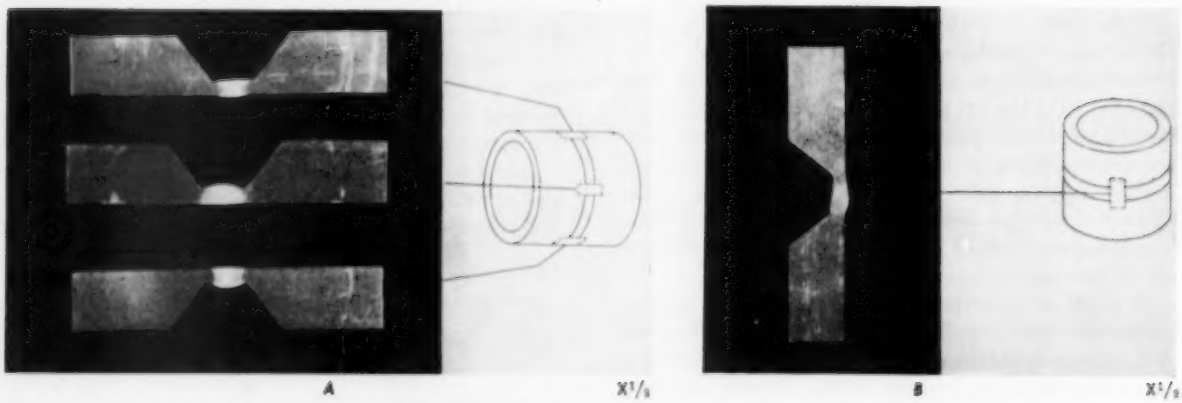
On thin-walled stainless steel piping (Schedules 5 and 10) at least two inert-gas tungsten-arc passes are ordinarily necessary to provide sufficient weld reinforcement around the circumference of the pipe. The first pass is usually made without filler metal and the second pass with filler metal. With the insert ring high quality welds are readily made in one pass. The cross sections of pipe welds made in one pass without and with the welding insert are shown in Fig. 22.

By increasing the ID to OD width of the insert ring, i.e., increasing the "supply" of weld metal, the detrimental effect of "poor" fit-up can be minimized considerably. Cracking and burn-through which may occur with excessive gaps or offset can be more readily avoided with the insert ring.

The "offset" (misalignment) tolerances permissible without and with the use of insert rings are given in Table 1. The acceptable "gap" tolerances are given in Table 2. The limits are based on the ability of the average shop welder to obtain consistently acceptable welds. The advantages of using insert rings are obvious where less than "perfect" fit-up is encountered. In the laboratory "gaps" exceeding $^3/_{32}$ in. have been bridged consistently in Type 347 stainless steel piping without leaving root-pass cracks.

Table 1—Permissible Offset Tolerances for Root-Pass Welding of Various Materials

End preparation	*Welding condition*	*Carbon steel*	*$1^1/_4Cr - {}^1/_2Mo$ and $2^1/_4Cr - 1Mo$ alloy steel*	*Stainless steel*
"V" bevel	Without filler wire	$^1/_{64}$	$^1/_{64}$	$^1/_{64}$
	With filler wire	$^1/_{16}$	$^1/_{16}$	$^1/_{32}$
	Insert ring	$^3/_{32}$	$^3/_{32}$	$^1/_{16}$–$^3/_{32}$
"U" bevel	Without filler wire	$^1/_{32}$	$^1/_{32}$	$^1/_{64}$
	With filler wire	$^1/_{16}$	$^1/_{16}$	$^1/_{32}$
	Insert ring	$^3/_{32}$	$^3/_{32}$	$^1/_{16}$–$^3/_{32}$
"Flat-land" bevel	Without filler wire	$^1/_{32}$	$^1/_{32}$	$^1/_{64}$
	With filler wire	$^1/_{16}$	$^1/_{16}$	$^1/_{32}$
	Insert ring	$^3/_{32}$	$^3/_{32}$	$^1/_{16}$–$^3/_{32}$



A X1/2 B X1/2

Fig. 21 Contour of root-pass welds in stainless steel piping made with the welding insert ring (A) in fixed position horizontal pipe and (B) in fixed position vertical pipe.

Table 2—Permissible Gap Tolerance for Root-Pass Welding of Various Materials

End preparation	Welding condition	Carbon steel	$1^1/_4Cr - {}^1/_2Mo$ and $2^1/_4Cr - 1Mo$ alloy steel	Stainless steel
"V" bevel	Tight butt	1/32	1/32	1/64
	Filler wire	1/32	1/32	1/32
	Insert ring	1/16	1/16	1/16
"U" bevel	Tight butt	1/32	1/32	1/32
	Filler wire	1/32	1/32	1/32
	Insert ring	1/16	1/16	1/16
"Flat-land" bevel	Tight butt	1/32	1/32	1/32
	Filler wire	1/32	1/32	1/32
	Insert ring	1/16	1/16	1/16

Another already mentioned advantage of the insert ring welding method is that it provides for control of the weld metal composition in the root pass. This is particularly important on certain stainless-steel materials which have a composition highly susceptible to microcracking in the molten weld metal. For example, cracking difficulties are common in the columbium-stabilized Type 347 grade[2] widely used in power and chemical process piping where the operating temperatures and/or corrosive service conditions require the use of stabilized austenitic stainless steels.

The susceptibility of Type 347 weld metal to cracking

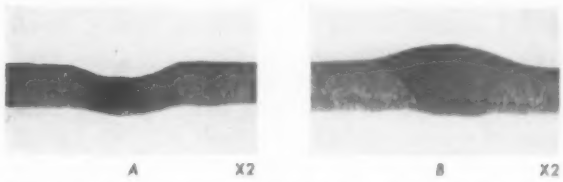


Fig. 22 Cross sections of welds in 6 in. Schedule 5 (0.109 in. wall) made (A) without insert ring and (B) with insert ring

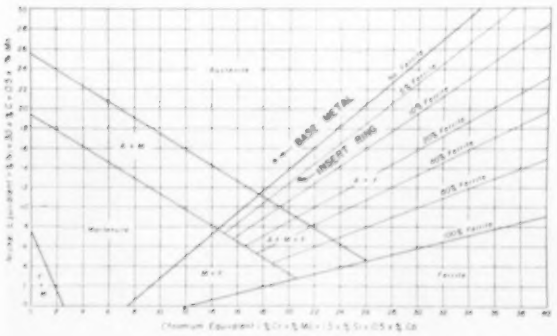


Fig. 23 Diagram used for estimating the austenite-ferrite microstructure of stainless steels (Schaeffler[3])

Fig. 24 Sketch illustrating "mixing" of welding insert ring metal and pipe base metal

is particularly serious when the composition is fully austenitic. A fairly accurate method used by the metallurgist for estimating the structure in stainless steels employs the Schaeffler diagram shown in Fig. 23.[3]

In one recent fabrication job, the Type 347 stainless-steel pipe received had the following chemical composition: carbon, 0.08%; manganese, 1.54%; silicon, 0.51%; chromium, 17.64%; nickel, 11.70%; columbium, 0.87%.

This composition falls within the range specified in the applicable ASTM and AISI Specifications. As indicated in Fig. 23, the above composition tends to produce a fully austenitic structure which, in this grade, is considered particularly crack sensitive. Thus, by inert-gas tungsten-arc welding without an insert ring it was impossible to avoid cracking in this stainless-steel grade, even though root welds in joints with the "flat-land" type groove preparation generally exhibited less cracking than root welds deposited in the U-type groove preparation. The only successful method of avoiding cracking was to insert rings of a composition resulting in a partially ferritic structure. Thus, cracking in the above pipe was avoided with an insert ring of the following composition: carbon, 0.07%; manganese, 1.86%; silicon, 0.86%; chromium, 18.48%; nickel, 9.66%; columbium, 0.98%.

According to the Schaeffler diagram this composition is likely to contain a ferrite content of approximately 7%, the balance being essentially austenite. During welding the heat of the arc will produce mixing between the molten insert ring metal and part of machined lip, as illustrated in Fig. 24. The resulting weld metal will contain approximately 50% of base metal and 50% of insert ring metal. Actual weld tests bore out these considerations. The resulting weld deposit contained approximately 3% ferrite as checked by magnetic measurements. Microcracking was completely eliminated.

Good results have been obtained with insert rings on various commercial carbon steel piping, chrome-moly alloy steel piping and stainless steel piping of Types 304, 310, 312, 316, 321 and 347.

Future Development

Although much has already been written about the application to piping of the different inert-gas welding processes, a great many new procedures and processes are in various stages of development or are already being used under production conditions.

Important new developments are the automatic welding of the root pass and/or the whole pipe weld with the tungsten and/or consumable electrode processes. The use of CO_2 and/or nitrogen for shielding and/or purging offers promise of allowing significant reduction in the welding costs. Ceramic, sandcore and collapsible back-up fixtures and back-up fluxes and glass tapes have also shown some merit.

Bibliography

1. Risch, T. A., and Dohna, A. E., "Consumable Insert Method of Root Pass Welding," The Welding Journal, 33, (7) 670–679 (1954).
2. Thielsch, H., "Physical Metallurgy of Austenitic Stainless Steels," *Ibid.*, 29, (12) Research Suppl., 577-s to 621-s (1950).
3. Schaeffler, A. L., *Metal Progress*, 56, 680 (1949).

INERT-GAS METAL-ARC WELDING CLADS 102-IN. PROPELLER

Propeller company saves time, cuts cost using inert arc welding to build up nickel vanadium steel

BY C. S. SHERMAN

Established over 45 years ago, the Coolidge Propeller Co., Seattle, Wash., includes among its services a repair department for all types and makes of propellers. It was to this department that two 102-in. diameter cast nickel vanadium steel ferry propellers were brought for repair. The blade surfaces had become badly pitted from hard service in northern waters and new surfacing was needed that would protect them from future erosion.

Previous repairs had been made in a local shipyard using stainless electrodes on small eroded areas. Coolidge, however, decided that a better cladding operation could be done with the inert-gas metal-arc process. While they had made similar repairs on manganese bronze and aluminum bronze propellers, this was the first use of inert-gas metal-arc welding for repairs using stainless steel wire on nickel vanadium steel.

The results more than justified their decision. Not only were they able to deposit the stainless cladding in record time, but they obtained a sound uniform deposit that required less grinding than normal to give surfaces the smooth final finish desired. In addition, the entire blade areas were given sure protection against service erosion while holding repair costs to a bare minimum.

Using the stringer bead technique, welding started on the thin edge of each blade and progressed, small areas at a time, to the heavier hub end (see Fig. 1). Each area was welded for a short period only. The propeller was rotated and each of the three blades worked on alternately to distribute the heat uniformly and hold distortion to a minimum (see Fig. 2).

Cladding the 15,552 sq in. used 312 lb of welding wire. High current density of the welding arc by use of small diameter electrode wire produced excellent fusion to

C. S. Sherman is Technical Supervisor, Air Reduction Pacific Co., San Francisco, Calif.

Fig. 1 Welding began on the thin edge of each blade and progressed, small areas at a time, toward the hub end

Fig. 2 The welder alternates work on each of the three blades, cladding in small areas for short periods only

Fig. 3 The inert-gas metal-arc method of welding obtained a uniform deposit, reducing the amount of grinding necessary to produce a smooth surface

the deeply pitted base metal, maintaining, at the same time, a light, uniform deposit of stainless clad above the blade surface.

Welding completed, the propellers were straightened repitched, balanced and ground to smooth surface (see Fig. 3).

GIANT STEEL RINGS FOR LINCOLN TUNNEL TUBE ARE FLAME-CUT

BY A. H. YOCH

When the rock boring in the New Jersey land section was completed last winter on the Port of New York Authority's Third Lincoln Tunnel Tube under the Hudson River, the first consignment of huge steel rings produced by Baldwin-Lima-Hamilton, Eddystone Division, was on hand, ready for assembly.

A total of 145 complete rings, each ring composed of 10 segments, is necessary to line approximately 750 linear feet of tunnel under the New Jersey Palisades. These rings are produced to taper, giving a gradual longitudinal curve to this section of the tunnel. When assembled, each ring will measure approximately 31 ft in diameter. (Upon completion in 1957, the $100,000,000 two-lane, trans-Hudson tube will increase the annual capacity of the tunnel by 50%.)

One of the operations at Baldwin-Lima-Hamilton in the production of the segments involves a unique

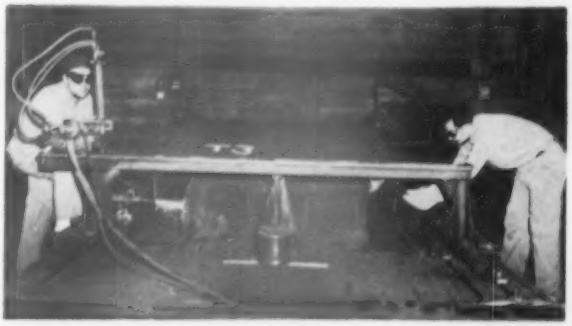


Fig. 1 The two portable cutting machines are shown moving toward completion of the flange cuts on each side of segment of giant steel ring

A. H. Yoch is Technical Representative, Philadelphia District, Air Reduction Sales Co.

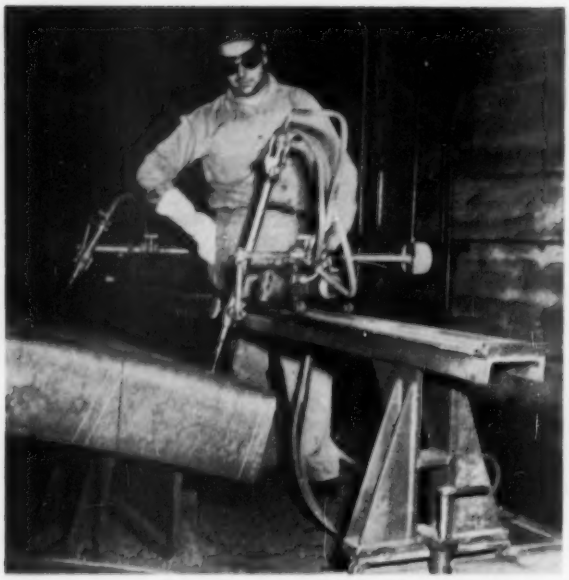


Fig. 2 Close-up of portable cutting machine used for end cut; at same time another machine is cutting other end

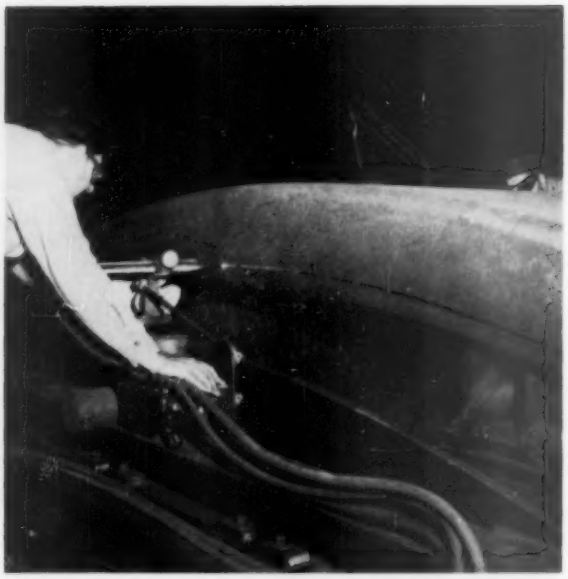


Fig. 3 Flame cutting of flanges on each side is performed simultaneously by two portable cutting machines

flame-cutting fixture where five portable cutting machines are used to trim each segment to specified dimensions.

After flat boiler plate—$^1/_2$ in. thick—has been heated and press-formed into a curved U-shaped section (one segment), it is shot-blasted to remove mill scale and then placed on the fixture. Once positioned, the heavy segment is not moved again until all cutting is completed. Agile cutting machines provide mobility, going to work on the segment at cutting speeds averaging 14 ipm.

The quintuple setup of cutting machines works on a two, two and one sequence. Two cutting machines flame cut the curve on the side flanges on each side simultaneously. A special parallelogram device built from standard portable parts permits the torch to follow the grooved template which conforms to the shape of the cut on the flanges. Flange cuts completed, the two end cuts are made at the same time by a cutting machine at each end. The fifth cutting machine is used for a special "keystone" cut, required on only one segment in ten.

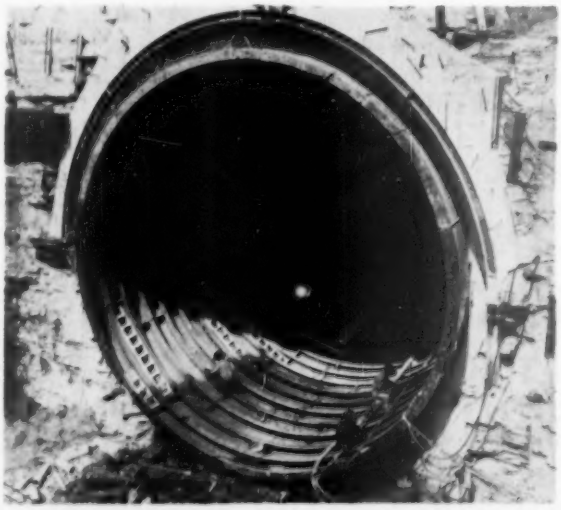


Fig. 4 Installation of the flame-cut segments is in progress at mouth of the new tunnel

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SUBMERGED-ARC WELDS PASS X-RAY TESTS

Submerged arc welding was recently put to the test in the fabrication of a number of heavy-walled pressure vessels at Cameron Iron Works, Houston, Tex. The largest of these vessels had a wall thickness of 7 1/2 in. and was required to withstand a test pressure of 27,000 psi. This meant that weld quality had to be of the highest order. All welds had to pass 100% X-ray inspection before the vessels were released for shipment. The sound, porosity-free submerged-arc welds passed this rigid requirement the first time. According to company officials, this job couldn't have been done economically without the help of high-speed submerged arc welding.

The largest pressure vessel was made in three sections of forged AISI 1029 steel two of which are shown in Fig. 1. This assembly measured 44 3/4 in. in length by 24 in. in diameter. Inside diameter was 9 in. with a wall thickness of 7 1/2 in. The weld joint design used is illustrated in Fig. 2. The nose of this joint was 1/16 in. thick. From this nose a 37 1/2 deg bevel rose to a level 3/4 in. above the inside diameter. The remaining bevel was made 7 1/2 deg from the vertical to the outside diameter. A backing ring, 1 in. wide, 3/16 in. thick and with a 1/16-by 1/4-in. shoulder was inserted for fit-up purposes. This ring was held by tack welds.

Based on a story by the Linde Air Products Co.

Before welding, the weld area was preheated to 400–500° F. A submerged-arc welding head was then positioned over the joint and the welding operation started (see Fig. 3). Four hundred passes were required to deposit 265 lb of weld metal in each of these two joints. Each pass was visually inspected to make sure that

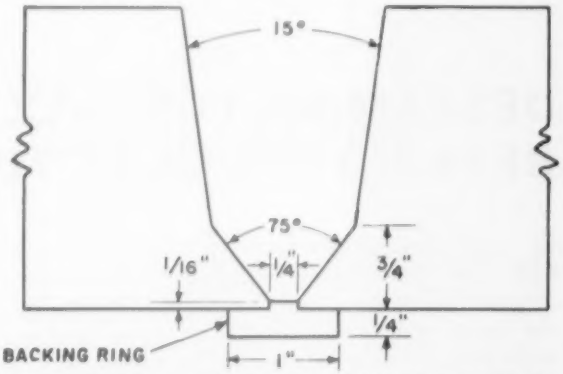

Fig. 2 This diagram shows the weld joint design used for the pressure vessels. A backing ring was used for fitting and to facilitate complete weld penetration without the need of inside finishing

Fig. 1 The largest of the pressure vessels was made in three sections of forged AISI 1029 steel, two of which are shown above. The wall thickness of this pressure vessel measures 7 1/2 in.

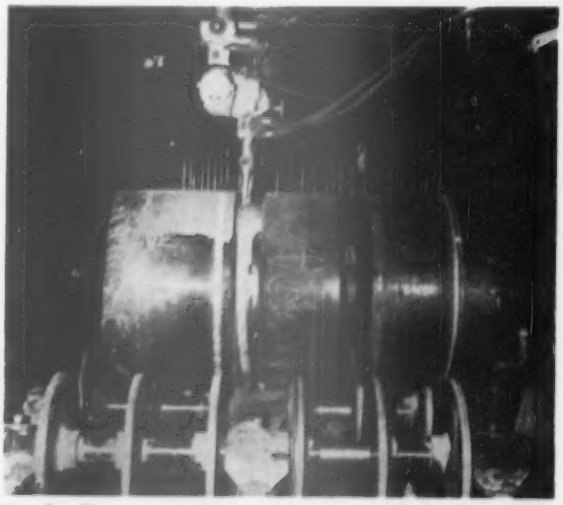

Fig. 3 The strong, clean welds were made by positioning a submerged-arc welding head over the weld area as illustrated above. Five hundred and thirty pounds of weld metal were deposited in the two weld joints in 800 passes

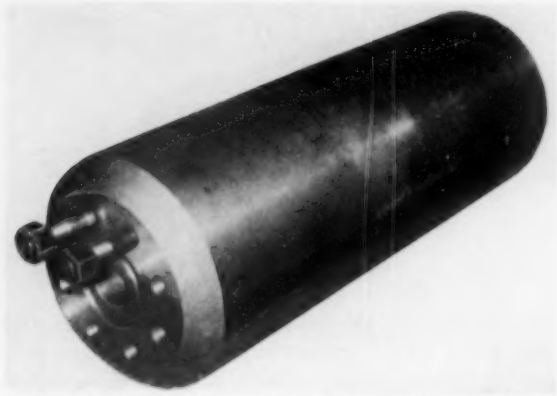

Fig. 4 A completed vessel, machined and ground to a smooth finish

the welds were clean and free from porosity and cracks. Because the welding conditions were precisely controlled, no weld cracking ever occurred.

The first welding pass, which was required to be completely welded to the backing ring, was put at 475 amp 28 v , using $^1/_8$-in. high-tensile steel welding wire. The welding wire size was then changed to $^5/_{32}$ in. and the welding current gradually increased to 700 amp 34 v for the fourth pass and succeeding passes. Welding speed was 18–20 ipm. Grade 80, flux composition was used for all the welds.

After welding, the entire vessel was stress relieved and the welds were ground or machined flush with the outside diameter (see Fig. 4). Inside finishing was not necessary and would have been difficult because the end openings were only 2 in. in diameter

DESEAMING TORCHES CUT BARGE REPAIR TIME, COST 70 PER CENT

By using deseaming torches to remove old plates from barge bottoms, the Consolidated Western Steel Division of United States Steel Corp., Orange, Tex., cut operating time from 4 days per barge to $1^1/_2$— and cut costs approximately $500 per barge.

The steel company had 21 barges to rebottom. Plant engineers decided to roll the barges over in the water, remove the old plate and then weld new plate on the frames. However, before removing the old plates it was necessary to "open" seam welds and plug welds, and remove rivets. Four standard flame-gouging torches used on the first barge were found to be too costly and slow.

Two deseaming torches were set up for the job and the remaining work was completed with substantial savings. Deseaming torches cut a flat pass in metal at high speeds, with minimum nicking into the support members below the plate (see Figs. 1 and 2).

Oxygen consumption on this job was approximately 55% less with deseaming torches, than with conventional flame-cutting equipment. In contrast to other flame processes used on steel, deseaming torches have a low-velocity oxygen stream, and pressure may be varied according to the depth of penetration desired.

Based on a story by the Linde Air Products Co.

Fig. 1 Deseaming torches open transverse plate welds in barge bottoms about 7 times faster than conventional cutting torches

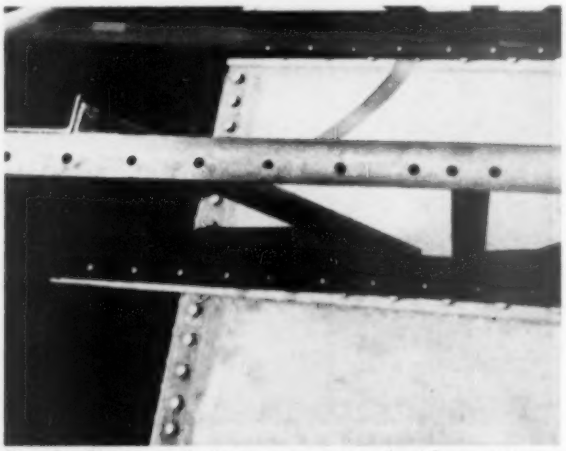

Fig. 2 Plates and rivets are removed with a minimum nicking to the frame. When new plates are submerged-arc welded in place, the barge is as good as new

Fig. 1 Made of aluminum, inert-gas metal-arc tank welded trailers and semitrailers have a greater load capacity and last longer

INERT-GAS METAL-ARC WELDED ALUMINUM UPS TANK-TRUCK CAPACITY

The problem of how to get bigger payloads in truck trailers and semitrailers, and still not exceed legal limitations, is being answered by Butler Mfg. Co., Minneapolis, Minn., with inert-gas metal-arc welding and weight-saving aluminum. The semitrailer shown in Fig. 1 holds 7950 gal—700 gal more than a similar trailer with a steel tank.

Inert-gas metal-arc welding has also eliminated expensive weld cleaning—welds need only a light grinding and they are finished. Upon completion, all tanks are tested by compressed air. The high quality of inert-gas metal-arc welds has practically eliminated pinholes. These tanks are used mostly for hauling petroleum products, and the inert-gas metal-arc welded aluminum tanks have a greater resistance to corrosion than previously used steel tanks.

A semitrailer requires about 1100 lineal ft of high-quality inert-gas metal-arc welding. All welding is performed with equipment shown in Fig. 2. The new high-strength, high-ductility alloys used range in thickness from $^{3}/_{32}$ to $^{1}/_{4}$ in.

To allow freedom and easy movement around and inside of the big tanks during welding, the welding wire feed units are separated from the control cabinets and suspended from arms attached to each equipment unit.

This inert-gas metal-arc welding application is typical of the many varied jobs for which inert-gas metal-arc welding is being used in industry. In small shops and on huge production lines, inert-gas metal-arc welding is attaining new high-production speeds and unit quality.

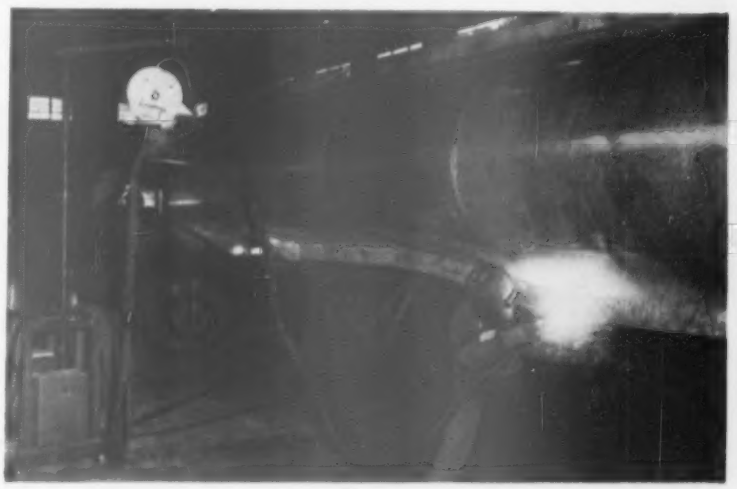

Fig. 2 Wire feed units are separated from their control cabinets and suspended from arms attached to the inert-gas metal-arc welding machines; this installation was designed to allow easy movement around and inside the tank during welding

Based on a story by the Linde Air Products Co.

Society News

Many Features Contribute to
Eventful Thirty-Sixth National Fall Meeting

Some 1200 attendees participate in the many varied activities that filled the week of October 17–21 in Philadelphia

President J. H. (Joe) Humberstone, officially welcomed the Society's members and guests at the opening session on Monday morning

The Adams Lecture was well attended and very interestingly presented by La Motte Grover of Air Reduction Sales

With the energetic and resourceful members of the AWS Philadelphia Section acting as hosts, the Thirty-Sixth National Fall Meeting of the AMERICAN WELDING SOCIETY drew approximately 1200 members and guests to the Bellevue-Stratford Hotel in the "City of Brotherly Love," during the week of Oct. 17–21, 1955.

The meeting got off to an excellent start on Monday, October 17, with a welcoming address by President Joe H. Humberstone. The principal features that followed included the Adams Lecture; 21 technical sessions, covering a grand total of 61 papers; inspection tours; presentation of honor awards; and numerous social events and business meetings.

Honored with Awards

Highlight of the opening session in the morning was the Adams Honor Lecture presented by La Motte Grover of Air Reduction Sales Co. In his lecture, "An Interpretation of Research and Experience in Structural Welding," Mr. Grover devoted particular attention to the brittle fracture problem. This lectureship was established in 1943 to honor the founder and first President of the AMERICAN WELDING SOCIETY and is awarded annually to an outstanding scientist or engineer who has made a new or distinctive development in the field of welding.

At this same session, Nikolajs Bredzs, Armour Research Foundation, was awarded the Lincoln Gold Medal for the paper judged as the most original contribution to the advancement and use of welding and published in "THE WELDING JOURNAL" during the 12-month period ending this July. His winning article, "Investigation of Fac-

Nikolajas Bredzs, Armour Research Foundation, was presented the Lincoln Gold Medal and Certificate by President Humberstone

Monroe Edwards, Georgia Institute of Technology, won the A. F. Davis Undergraduate Welding Award, first prize

Approximately 450 AWS members and guests passed by the President's Reception Line, meeting our national and section officers

The Society was honored by the presence of its founder and first president, Dr. Comfort A. Adams, and his charming daughter-in-law, in President Humberstone's reception line

tors Determining the Tensile Strength of Brazed Joints" was published in the November 1954 issue. This medal is awarded annually, and is sponsored by J. F. Lincoln, president of the Lincoln Electric Co.

Monroe Edwards, Georgia Institute of Technology and "The Georgia Tech Engineers" received the A. F. Davis Undergraduate Welding Award for the best student paper on welding to appear in an undergraduate publication during the past year ending June 1st. William J. Gress, student at University of Florida, and the *Florida Engineer* received second prize.

At the National Dinner on Monday evening, William Spraragen, Director of Welding Research Council, was presented with an Honorary Membership in the AMERICAN WELDING SOCIETY in recognition of his eminence in the welding profession and for having served the AMERICAN WELDING SOCIETY faithfully and efficiently for many years.

Mr. Spraragen was Editor and Business Manager of THE WELDING JOURNAL from 1922 to 1955. He was the Editor of the first two editions of the WELDING HANDBOOK. He served the SOCIETY as its Technical Secretary from 1927 to 1942. He concurrently served as Executive Secretary of the Welding Research Council from 1935 to 1945, when he became Director of that organization. In addition, he served as Secretary of the American Bureau of Welding from 1921 to 1936 and as Secretary of the Division of Engineering of the National Research Council from 1920 to 1934. He is author and co-author of some 70 critical Reviews of the Literature and other papers and book sections on practically every phase of welding. In 1940 he was awarded the Samuel Wylie Miller Memorial Medal for his outstanding work.

Also honored at the National Dinner was John J. Chyle, A. O. Smith Corp., who was presented the Samuel Wylie Miller Medal for contributing conspicuously to the advancement of welding. He has been active in welding for many years.

Mr. Chyle has been Director of Welding Research for the A. O. Smith Corp., since 1936. He joined that organization in 1925 as a chemist in the Production Laboratory and in 1926 became Head of Welding Electrode Research.

He has invented and patented a number of welding electrodes and welding processes and developed the first extruded, all-position type of electrode in 1927. During World War II he was a member of the Subcommittee on Welding of Armor and participated in the work essential to the production of the atomic bomb, which was part of the Manhattan District Project. In addition to being the author of numerous technical papers, Mr. Chyle was the Adams Lecturer for 1951. He has served as Member of the Board of Directors, as Second Vice-President and is now First Vice-President of the AMERICAN WELDING SOCIETY.

Win Membership Drives

The winners of the 1954–55 Henry Neitzel Membership awards were formally announced at the National Dinner by "Ed" Dato, Chairman of the National Membership Committee. The top prize for the greatest net numerical gain went to the Houston Section with 64 new members; the Philadelphia Section was second with 55 new members; and Kansas City was third with 46 new members.

The Toledo Section was the winner for the greatest net gain percentagewise with a 46.3% increase, Kansas City was second with 43.8% and New Orleans was third with 31.5%.

Duly inscribed plaques were presented to the winning Sections through their representatives present at the meeting.

Technical Papers Well Received

Very few phases of welding were left untouched by the 61 papers which were presented at the 21 scheduled Technical Papers Sessions. The latest developments were reported upon by authorities in the field and in general the information was received with considerable interest by those present. They represented another milestone of progress.

Among the many diversified topics discussed by the authors were carbon-dioxide-shielded arc welding, resistance welding, weldability and research, structures, inspection and testing, shipbuilding, welding equipment, stainless steels, welding electrodes, applications, titanium, molybdenum, pressure vessels, aluminum, piping, brazing, maintenance and production. (A complete listing of all the papers is given in the October issue of THE WELDING JOURNAL, pages 1000-1011.)

For his outstanding Adams Lecture, La Motte Grover was presented the beautiful Adams Lecture Certificate

The National Dinner, attended by approximately 250, followed the President's Reception

The technical papers sessions were supplemented by an excellent educational lecture series given by Julius Heuschkel of the Westinghouse Electric Corp. His subject was "Mechanical Properties of Steel Weld Metals."

Many Business Meetings Held

There were many and varied business events throughout the week. They included Manufacturers Meeting on Wednesday morning, Interim Business Meeting on Wednesday afternoon, WRC University Dinner and Conference on Wednesday evening, Board of Directors Meeting on Thursday morning and Sustaining Members Luncheon on Thursday noon, in addition to several Technical Activities Committee meetings.

Social Events Enliven Convention

There were several social events to enliven the serious business proceedings of the Convention. The President's Reception on Monday evening was attended by nearly 450 members, guests and their ladies. The National Dinner, held later on the same evening, saw another large crowd of 250 enjoying the

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UNITED STATES STEEL

J. J. Chyle was awarded the Samuel Wylie Miller Memorial Medal and Certificate for meritorious achievement contributing to advancement of welding and cutting

For acknowledged eminence and exceptional accomplishments in development of welding art, William Spraragen was presented Honorary Membership in our Society

President Humberstone thanks and congratulates J. E. (Ed) Dato for a very successful year of activity and results as 1954–55 National Membership Chairman

held later on the same evening, saw another large crowd of 250 enjoying the relaxed, informal atmosphere and partaking of the festivities surrounding the presentation of the honor and membership awards. As an added attraction, "Si" Greenberg, the AWS Technical Secretary, gave an entertaining talk on some of the interesting places he had visited while touring Western Europe as a member of a team of 29 representatives from most of the free countries of Europe, plus the United States and Canada. This team was selected by the Organization for European Economic Cooperation, European Productivity Agency and the U. S. Foreign Operations Administration to tour about 50 outstanding industrial plants and research centers in 11 European countries; plants which were engaged in considerable welding fabrications.

Spot Light Shared by Other Events

Additional events of special interest included plant visits to the U. S. Naval Shipyard, Naval Base, Philadelphia, on Wednesday morning, and to the Baldwin-Lima-Hamilton Corp., Eddystone Division, Philadelphia, on Thursday morning. Almost 250 members took advantage of these tours, which proved to have an exceptional appeal for the visitors.

The Ladies' Program included entertainment at the Llanerch Country Club, a tour to Bucks County and Washington's Crossing, and a talk on antiques. The usual coffee hours and luncheons were held on Monday through Thursday.

Philadelphia Section Outdoes Itself

Looking back upon the 1955 National Fall Meeting, the members of the Philadelphia Section can point with pride to another successful activity. The Philadelphia Arrangements Committee was indeed a well-organized and smooth running team that seemed to have the situation well in hand at all times. Special credit and commendation must be extended to "Ernie" Goehringer, general Chairman of the committee; to "Gus" Garcia as Secretary; to "Byron" Gates and "Jim" McKinney who cooperated on the many detailed arrangements for the Meeting Sessions; to "Fred" Judelson, on the Dinner; to Mrs. Irrgang, on the Ladies' Entertainment; to "Al" Gordon, on Hospitality; to "Hal" Heivly, on Plant Visits; to "Dave" Thomas, Jr., on the President's Reception; to "Ken" Ostrom, on the Publicity; to "Ralph" Bradway, on Signs; to "Sam" Baum, on Technical: and to "Tom" Berg, on Transportation.

The Thirty-Sixth National Fall Meeting will long be remembered as an enterprise of unusual educational and inspirational values, as well as one marked by the exuberance of warm friendship.

President Humberstone's Address at the Interim Business Meeting in Philadelphia

As you will recall, the terms of the President and Vice-Presidents of the Society, your current Officers, became effective Nov. 5, 1954. Due to a change in the Society's fiscal year, their terms were extended beyond that of the normal one year, to a term ending May 31, 1956.

At our 36th Annual Business Meeting in Kansas City, on June 8, 1955, you were advised that, having been in office but seven months, we would defer presenting what would be an inadequate report until completion of a full year's term. We advised that, at this meeting, we would present an interim report and in May 1956, at our 37th Annual Business Meeting at Buffalo, we would provide complete reports for our full administration year.

Therefore, today your President will review the Society's activities during the past year and your Secretary will present an interim report which will record in detail the activities of the Board of Directors, the Districts, the Standing and the Special Committees.

In presenting my report, I will touch briefly on District reports of sectional activities, on some of the Standing Committee and Special Committee business for the year, and will only touch on one or two matters that have been handled by the Board during this past year. This summary, of course, will go into the published record. The Secretary's report, by Mr. Magrath, will dwell in detail on each of the District reports and each of the Standing Committee and Special Committee reports.

There are good indications of continued growth based on District reports of sectional activities in all parts of the country during the past year. In the Far West, the new Santa Clara Valley Section was established with a record-breaking charter membership. Work is progressing toward the formation of divisions of the Puget Sound Section at Richland and at Spokane, Wash., with the former nearing completion. Prospects are good for the formation of a new section in either Sacramento or Stockton.

In the Southwest, Fort Worth is planning to hold an organization meeting this fall which should result in the formation of a new section. Shreveport is now a new section, just organized last month.

In the Midwest, there is a strong possibility of a new section or division of the Cleveland Section in the Canton-Massillon area. Considerable interest regarding a division of the St. Louis Section has been shown at Fulton, Mo.

In the South, possible locations for new sections or section divisions include Charleston, S. C.; Savannah, Ga.; Jacksonville, Fla.; Tampa, Fla.; Memphis, Tenn.; and Baton Rouge, La. The South Florida Section is organizing section divisions at Tampa and West Palm Beach.

In the East, the newly formed Long Island Section is coming along nicely. There is a prospect of a division of the New York Section in the Westchester area of New York State, and the possibility of two new sections being started at Corning and Utica, N. Y.

The National Membership Committee report indicates that from Sept. 1, 1954 to Aug. 31, 1955, membership registration increased from 10,323 to 10,832, or a net increase of 509 members.

Over this same period, there was an increase of 25 Supporting Companies, going from 217 to 232. Five new sections were formed, including (as of the August 31st date) the Holston Valley Section at Kingsport, Tenn.; the Madison Section at Madison, Wis.; and the Nebraska Section at Omaha. The other two, previously mentioned, are the Long Island Section of New York City and the Santa Clara Valley Section at San Jose, Calif.

In 1954 our general economy suffered a slight setback and this was reflected in a number of membership cancellations, particularly Supporting Companies. However, I am happy to report that in 1955 we have not only overcome our losses but established substantial gains.

The National Publicity Committee completed, early this year, the 12-page institutional promotional booklet. Twenty-five thousand copies have been printed. The new booklet explains the purposes and activities of the Society and describes the benefits of membership. It will serve as a basic promotion piece of the Society. Major emphasis will be directed toward placing it in the hands of possible Sustaining and Supporting members. A copy has been mailed to every AWS member to remind him of what his Society is doing. Each member was urged to pass on his copy to a prospective member.

The Technical Activities Committee issued, in the period of Oct. 1, 1954, to Sept. 30, 1955, a total of 13 publications, eight new and five revised, among which is the new *Brazing Manual*. Work is progressing on standards, both new and revised, for a total of six different additional projects.

On Jan. 1, 1955, William Spraragen retired as Editor of the Journal after thirty-three years of invaluable service and the new Editor, B. E. Rossi, assumed his responsibilities. The same month marked the introduction of a new format for the Journal aimed principally at increasing the "reader's interest."

The Manufacturers Committee has been very active during the past year in connection with the Society's Welding Exposition and has coordinated its meeting sessions, when possible, with the Society's Convention Committee and its working Subcommittees, the Exposition and the Five-Year Plan Committees. Accordingly, the interim report is actually a coordinated summarization of the work of the three groups, the Manufacturers, the Exposition and the Five-Year Plan Committees.

It was called to the Society's attention that the American Welding Society might sponsor an advertising campaign designed to create and sustain a greater interest in welding. The Society's position, of course, is very much in favor of promoting welding all the way across the board—arc, gas and

Ed Dato presents the Award Plaque for the largest numerical gain in membership to the Houston AWS Section, as represented by H. F. Crick

The Toledo AWS Section, represented by L. E. Shanteau, was presented the Award Plaque for the largest percentage gain in membership

resistance welding. It was stressed that such a campaign should include all phases of welding and should preserve and increase the good will which we now enjoy in all segments of industry.

Incidentally, that subject has again become quite active at this particular session.

On the subject of AWS Welding Exposition, the Manufacturers Committee agreed and recommended to the Board of Directors of the SOCIETY that no attempt be made to reduce the size of the Welding Exposition at any time by a rationing of space or otherwise, because such a course of action would be backward rather than forward, would retard the welding industry and thereby directly retard the SOCIETY.

The entire question of space for exposition developed from the fact that rapid growth of interest in AWS Welding Exposition has created a need for a policy on this subject. It was agreed that every effort should be made to provide every welding exhibitor with the amount of space he wishes to purchase. Toward accomplishing this objective, it was agreed that "fringe" exhibits should not only be discouraged but should be prohibited, so as to allow sufficient space for wholly welding exhibits or exhibits directly related to welding.

The Five-Year Plan Committee studied the potential of a number of major city areas as localities for AWS Welding Expositions. Cities studied were Baltimore, Birmingham, Boston, Buffalo, Chicago, Cleveland, Columbus, Cincinnati, Detroit, Grand Rapids, Harrisburg, Houston, Indianapolis, Los Angeles—I sound like a train caller—Milwaukee, Minneapolis, New York, Philadelphia, Pittsburgh, St. Louis, San Francisco, Syracuse, Toledo, and Washington—so you can see they covered the country pretty well.

For the life of the contract with the National Metals Exposition, we cannot enter the cities of Chicago, Cleveland, Detroit, and Philadelphia. The AWS Exposition has now been held in Buffalo, Houston, and Kansas City, and it has grown to the point where few cities have the facilities it requires.

It was obvious that the prohibition against Chicago, Cleveland, Detroit and Philadelphia, all of which have the necessary facilities, was resulting in a constriction of the SOCIETY'S Exposition program. Accordingly, a cancellation of the contract with the National Metals Exposition was, regretfully, recommended to the Board of Directors so that, subsequent to the fall of 1956, the Society could hold welding expositions in the aforestated cities if it so chooses. That recommendation was accepted, approved and acted upon by the Board of Directors.

For its 1956 Welding Exposition, the AMERICAN WELDING SOCIETY will return to Buffalo, the one available city possessing adequate facilities. The Five-Year Plan Committee had no misgivings in regard to recommending a return because of the success of the second welding show and the fact that many exhibitors had expressed a desire to enjoy a return engagement at Buffalo as soon as possible.

The Five-Year Plan Committee then proceeded to formulate a plan which would assure the Society Exposition facilities for at least five years in advance. That work is in progress. Facilities have been secured at Philadelphia for the spring of 1957 and at Milwaukee for the spring of 1958, and it appears quite certain that we will be in Pittsburgh for the spring of 1959.

The Exposition Committee each year is assigned the task of producing and managing a welding exposition for the forthcoming year. The successful three past expositions at Houston, Buffalo and Kansas City are evidence of the Exposition Committee's efforts. At this time the Exposition Committee is working on the SOCIETY'S Fourth Welding Exposition at Buffalo in May 1956. The Buffalo Exposition will extend for three days—Wednesday, Thursday and Friday, May 8th, 9th and 10th.

The Technical Council of the Board of Directors is an appointed group of members of the Board of Directors commissioned with the task of handling all technical affairs of the SOCIETY for the Board of Directors.

In this connection, it also seeks out information from the Society members, the welding industry and users of welding, whereby the objects of the SOCIETY can be furthered technically.

With such scope as its charter, the Technical Council has been coordinating its activities and interests with numerous activities of the SOCIETY specifically assigned to other standing committees.

The AWS-ASME 1956 Joint Program Committee has made arrangements for a joint meeting of the AWS and ASME Metals and Engineering Division in the spring of 1956 at Buffalo. In other words, this particular group will be joining with us at Buffalo.

I would like to comment on one thing which I think is very worthwhile putting in the record, that we have finally again become very active in connection with our WELDING HANDBOOK, Fourth Edition. We have engaged the services of an editor to do nothing but work on the WELDING HANDBOOK. We are beginning to put together a committee that will be working with him in connection with the administrative matters involved in issuing a new Handbook.

In addition, I would like to point out that in THE WELDING JOURNAL as of the present time, in the new format, you may have noticed that you get more advice in connection with the matters handled by the Board, confronting the Board, as well as the technical activities of the SOCIETY through two pages in the JOURNAL, one dealing with "Things You Should Know" which have to do primarily with matters involving the Board, and another page that involves the activities of the Technical Activities Committee.

With these few remarks, relatively brief, covering a complete year's activity I should like to conclude my report.

Ed. Note: The detailed Interim Report of the Secretary will be mailed to any AWS member requesting same, upon his written request sent to Secretary, AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

Nearly one hundred and fifty AWS members and guests toured both a submarine and an aircraft carrier at the Philadelphia Naval Shipyard

John J. Chyle

AWS NATIONAL OFFICERS NOMINATED FOR 1956–57

The AWS National Nominating Committee has recently submitted its nominations for national officers for the 1956–57 fiscal year. The names of those who, in the opinion of the Committee, are best qualified to guide the destinies of the AMERICAN WELDING SOCIETY during the next year are as follows: John J. Chyle, President; Clarence P. Sander, First Vice-President; Gustav O. Hoglund, Second Vice-President; Francis H. Stevenson, John H. Blankenbuehler, George E. Linnert, and Gordon Parks, Directors-at-Large, 1956–59.

In addition to the above, the following four nominees for District Directors for 1956–57 have been selected by the duly appointed District Nominating Committees: Donald B. Howard, District 2; Thomas R. Berg, District 4; Frank G. Singleton, District 8; and Charles L. Breese, District 10.

Short biographies of these nominees follow herein.

Nominated for President

John J. Chyle

John J. Chyle graduated in Chemical Engineering from the University of Wisconsin in 1924. After working for one year at Smith Steel Foundry, Milwaukee, he joined the A. O. Smith Corp. as a chemist in the Production Laboratory. In 1926 he was named head of welding Electrode Research at A. O. Smith, and in 1937 he was appointed Director of Welding Research.

Mr. Chyle has invented and patented a number of welding electrodes and welding processes. The first extruded all-position type of electrode was developed by him in 1927. This original electrode was of the cellulosic titanium dioxide type which is now classified as the E6010 type.

Special alloy electrodes for the welding of high-strength alloy steels were also developed by Mr. Chyle and used extensively during World War II on aircraft landing gears, torpedo airflasks and bombs. Welding processes originated under his direction included those for the welding of low-alloy high-tensile steels.

Mr. Chyle is active in technical committees and in technical societies, including the AMERICAN WELDING SOCIETY, American Society for Metals, American Society for Testing Metals and the American Society of Mechanical Engineers. He helped to organize the Milwaukee Section of the AMERICAN WELDING SOCIETY in 1932 and was Secretary and Treasurer for about six years. In 1939 he was elected Vice-Chairman of the Milwaukee Section and was Chairman in 1940 and 1941.

Mr. Chyle also served on many other committees, such as the Chairman of the Automotive Committee, a member of the Technical Activities Committee of the AMERICAN WELDING SOCIETY, plus many other AWS committees. He also assisted in the preparation of many chapters of the 1950 edition of the WELDING HANDBOOK.

He was a director of the Society, elected for a period of three years, 1948–51. In 1955 he was awarded the Samuel Wylie Miller Medal for contributing conspicuously to the advancement of welding.

Some of his most recent talks were on "Practical Aspects of Welding Titanium Alloys" and "Factors in the Selection of Welding Processes"; he also gave the 1951 Adams Lecture which was entitled "The Welding of Copper by the Inert-Gas Metal-Arc Process."

Last year Mr. Chyle was elected as the 1st Vice-President of the AMERICAN WELDING SOCIETY for a term of one year.

Junior College and the University of

of the Los Angeles Section for the

Nominated for First Vice-President

Clarence P. Sander

Clarence P. Sander is General Superintendent, Vernon Plant, of Consolidated Western Steel Division of United States Steel Co. at Los Angeles, Calif.

Mr. Sander was formerly with the Pacific Car & Foundry Co., Seattle, Wash., and Portland, Ore., in the Engineering Department, and Chief Estimator and later Assistant General Manager for many years, handling labor problems and Production for both plants.

He joined the Western Pipe and Steel Co. in 1934 as General Superintendent of Shop and Field Operations, Southern Division, until it became a part of the Consolidated Western Steel.

Mr. Sander is a graduate of Wilson's College, Seattle, Wash., with postgraduate work in engineering at the University of Washington and the Univerity of Southern California.

He has been a member of AWS for 21 years, Sustaining Member since 1937; Past-Chairman of Los Angeles Section AWS; Vice-President Western District AWS, 1946–47; 2nd Vice-President of American Welding Society, 1955–56, Member of the Welding Research Council and the American Society of Metals and API, besides various social and civic clubs.

His experience covers a broad field in welding such as railroad equipment, shipbuilding, pipe line, boilers, penstocks, pressure vessels, oil refinery installations, steel structures, tank and various other welded products.

Nominated for Second Vice-President

Gustav O. Hoglund

G. O. Hoglund is head of the Welding Section of the Alcoa Process Development Laboratory. He is a native of Milwaukee, Wis. After attending that city's primary and preparatory schools, he studied aeronautical engineering at the University of Michigan, and was graduated in 1925 with a Bachelor of Science degree.

For the next two years Mr. Hoglund worked in the Bureau of Aeronautics, Navy Department, in Washington, D. C., designing airplane propellers. His next position was at the University of Minnesota where he served as assistant professor of aeronautics during the college term of 1927–28.

Mr. Hoglund first became affiliated with the Aluminum Company of America in 1928 and for the next two years was employed in the Central Metallurgical Division. In 1930 he was placed in charge of the development of welding processes for aluminum.

He is now in charge of the Welding Division in the Alcoa Process Development Laboratories. He is also chairman of Alcoa's Subcommittee on Joining and proudly wears Alcoa's twenty-five year pin.

Mr. Hoglund is the author of a number of technical articles which have appeared in the Welding Journal, the SAE Journal and Mechanical Engineering. He has been active in the American Welding Society, serving as a member and chairman of many committees. His AWS activities include the following: Board of Directors; Technical Council; Technical Papers Committee—Past Chairman; Finance Committee; AWS-ASTM Committee on Filler Metal; Subcommittee III—Aluminum and Aluminum Alloy Filler Metal—Chairman; Brazing Committee; and Pittsburgh Section—Past Chairman.

In addition, he has served on the Boiler Code Subcommittee on Welding of The American Society of Mechanical Engineers.

In 1939 Mr. Hoglund was the recipient of the Lincoln Gold Medal for a technical paper on "Spot Welding the Aluminum Alloys."

Nominated for Director-at-Large, 1956–1959

John H. Blankenbuehler

John H. Blankenbuehler was born in Elizabeth, Pa., and graduated from Lehigh University with a degree of Electrical Engineer. He then worked at the Westinghouse Electric Corp. in Pittsburgh for 23 years, starting as a design engineer, and was manager of Welding Apparatus Engineering in charge of all engineering on motor generator sets, transformer welders, automatic welding equipment and welding accessories at the time he left Westinghouse in 1946. Since then he has worked for Hobart Brothers Co. in Troy, Ohio, as design engineer.

While at Westinghouse he secured 30 patents on welding apparatus. He is a member of the Honorary Engineering Society Tau Beta Pi and the Honorary Military Society Scabbard and Blade. He is also a Fellow in the American Institute of Electrical Engineers and has been a director of the Dayton Section of the American Institute of Electrical Engineers. He is a member of the AIEE Committee on Electric Welding.

He is a member of the American Ordnance Association, American Society for Metals, the Ohio Society of Professional Engineers, and is registered professional engineer in Pennsylvania and Ohio.

He is a member of the Troy Rotary Club. During World War II he received a Certificate of Commendation from the United States Navy for electrical design work done for the Navy. He has presented a number of papers before various sections of the AIEE and AWS. He has been Chairman and Secretary of the Dayton Section of the American Welding Society, and since 1952 has been District Director of District 4 and then District 5 of the American Welding Society. During that time he was a member of the Executive Committee of the National Board of Directors and is now Chairman of the Sections Advisory Committee composed of the District Directors. He has also served on the National Membership and Publicity Committees.

George E. Linnert

Born in 1916 at Chicago, Ill., George E. Linnert joined the Republic Steel Corporation at Chicago in 1935 to spend six years in metallurgical activities on plain-carbon and low-alloy steels in Republic's South Chicago steel plant and the Grand Crossing wire mill. In 1941 he accepted a position with the Rustless Iron and Steel Corp. at Baltimore, Md. which later became part of the Armco Steel Corp. During the past fourteen years at Baltimore he has devoted himself to metallurgical research work on stainless and heat-resisting steels, particularly the welding of these materials. During the years of World War II, he conducted several research projects for the National Defense Research Council and the Office of Naval Research on the development of improved armor welding electrodes and the weldability of alloys for high-temperature service. He is now in charge of the welding research group in the Armco Research Laboratories at Baltimore.

Mr. Linnert has instructed classes in Advance Welding Metallurgy at Johns Hopkins University. In addition, he is the inventor of the "flux-injections" process for torch cutting stainless steels.

He is the author and co-author of technical papers, and the Second Edition of the book *Welding Metallurgy* published in 1949 by the American Welding Society.

He is a member of the American Society for Metals and the American Welding Society and is Past-Chairman of the AWS Maryland Section.

Gordon Parks

Gordon Parks was born in Wilkinsburgh, Pa., on July 26, 1913. The schools he attended include Rutherford

District Representatives on the National

The new Welding Handbook is

Junior College and the University of Pittsburgh. Following his formal education, Mr. Parks was employed in the Pennsylvania gas and oil fields until 1940 when he joined the Westinghouse Electric Corp. At Westinghouse, he worked in the Welding Research Laboratory and the Headquarters Manufacturing Division as a manufacturing engineer.

In 1945, Mr. Parks moved to Des Moines, Iowa, where he became a welding engineer for Solar Aircraft Co.'s midwest plant. He was promoted to chief welding engineer in 1949 and continues to serve in this capacity.

As a long-time member of the AMERICAN WELDING SOCIETY, Mr. Parks was instrumental in organizing the AMERICAN WELDING SOCIETY Iowa Section of which he has served as chairman. He has presented numerous talks on welding before the local AMERICAN WELDING SOCIETY Section and other engineering groups. At present Mr. Parks is a member of the Welding Research Council Series Spot Welding Subcommittee. Other technical society activities include founding of the Des Moines chapter of the American Society for Metals of which he is a past chairman, and the Des Moines Engineering Society.

In community activities, Parks is presently associated in various capacities with the Junior Achievement Program and the Girl Scout Executive Committee Council.

Francis H. Stevenson

Francis H. Stevenson received formal education at the Nutana Collegiate Institute at Saskatoon, Saskatchewan, Canada, and teacher training at the University of California at Los Angeles. He spent twelve years at Lockheed Aircraft Co. where he started as a welder on the bench and advanced to the position of assistant superintendent of manufacturing, Plant A II. During this time, he also conducted classes in welding for the Burbank Evening High School. One year was also spent at the Jet Propulsion Laboratory of the California Institute of Technology as welding superintendent. He has been with Aerojet-General Corp. for the past five years as Production Engineer—Welding.

Mr. Stevenson has written a number of articles for THE WELDING JOURNAL and for trade magazines. He has also presented a number of papers at the national AWS meetings. He has been a member of the AWS for the past seventeen years and was Chairman of the Los Angeles Section for the year 1942–43 and served as chairman of the Aircraft and Rocketry Panel for two terms.

Nominated for District Director, 1956–1957

Donald B. Howard
District 2, Middle Eastern

Donald B. Howard is supervisor of metallurgy and welding at the General Laboratories, Research and Development Department, of American Car and Foundry, a division of ACF Industries, Inc., at Berwick, Pa.

During his eight years with ACF he has devoted much effort to the evaluation of new welding materials and processes and their subsequent application in the railway equipment and ordnance field. Prior to his association with ACF he was a metallurgist at the American Steel and Wire Division of United States Steel.

Mr. Howard was graduated from Colgate University in 1939. He is a member of the AMERICAN WELDING SOCIETY of which he is currently the District Director for District No. 2 and serves on the SOCIETY'S National Board of Directors. He is also a member of the American Society for Metals.

Thomas R. Berg
District 4, Southeast

Thomas R. Berg is presently associated with Wingerter Laboratories, Inc., Little River Station, Miami, Fla., being engaged principally in steel and welding inspection.

Mr. Berg's first association with welding came in 1916, when he was an electric welder with the Electric Welding Company of America, New York City. From 1917 to 1921, he was employed by the Luckenbach Steam Ship Line, also of New York City. He then became superintendent of the Electric Welding Department of the United Marine Contracting Corp., of the same city. From 1924 to 1936 he was welding supervisor and estimator with the J. K. Welding Co., New York; from 1937 to 1948, he was welding foreman, Shipbuilding Division, Bethlehem Steel Co., Brooklyn; from 1948 to 1952 he was steel inspector for the Haller Testing Laboratories. New York City; and in 1953 he began his association with the Wingerter Laboratories.

Mr. Berg is also an approved inspector of welding in the City of New York, Department of Housing & Building.

JOIN AWS!

Through membership in AWS you keep abreast of the latest developments in welding, welding engineering, welding metallurgy and procedures, by the contacts you make and through its local and national meetings and publications. Investment in AWS membership costs less than your daily newspaper, but brings you tremendous and perpetual dividends, and information on how to produce improved products, increase productivity, and lower production costs through modern welding procedures. Send for descriptive brochure to AMERICAN WELDING SOCIETY 33 West 39th Street, New York 18, New York.

He is co-founder and past-chairman of the South Florida AWS Section. He is now Secretary of this same group.

Frank G. Singleton
District 8, Midwest

Frank G. Singleton is a native of Kansas City. He served in World War II as squadron commander, Army Air Force. He is presently in the Army Air Force Reserve.

Mr. Singleton has been a member of the AMERICAN WELDING SOCIETY for many years and at present is vice-chairman of the Kansas City Section. He was local chairman of the 1955 Kansas City Arrangements Committee.

He is the owner of Singleton Welding Supply Co., 512 E. 18th St., Kansas City, Mo.

Charles L. Breese
District 10, Western

Charles L. Breese has been active in the glove manufacturing business since 1934 and is president and sole owner of John Tillman & Co., 1561 W. 19th St., Long Beach 10, Calif.

Mr. Breese joined the AMERICAN WELDING SOCIETY about twelve years ago, and has been on the local board over ten years. He was secretary in 1950–51, vice-chairman for 1952–53, and chairman 1953–54.

The John Tillman Co. was an exhibitor in the first AWS Show in Houston, Tex.; it is also an associate member of the National Welding Supply Assn.

Mr. Breese has been a member of the Long Beach Chapter of Kiwanis for the past four years.

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District Representatives on the National Nominating Committee

The District Nominating Committees have also selected the eleven nominees for District Representatives on the National Nominating Committee which will select the national officers for the 1957–58 term. The names of their candidates are as follows:

District No.	*Nominee*
1	Sidney Low, research engineer, Chapman Valve Manufacturing Co. Indian Orchard, Mass.
2	Julius Naab, mechanical engineer, Ingersoll-Rand Co., Phillipsburg, N. J.
3	W. F. Buchanan, foreman of welders, Cooper Bessemer Corporation, Grove City, Penna.
4	R. E. Lorents, Jr., division metallurgist, Combustion Engineering, Inc., 1032 W. Main St., Chattanooga 2, Tenn.
5	Howard B. Cary, welding superintendent, Marion Power Shovel Co., Marion, Ohio
6	J. R. Stitt, research and welding engineer, The R. C. Mahon Co., P. O. Box 4666, Detroit 34, Mich.
7	W. LeRoy Palmer, Industrial Engineering Div., Deere & Co., Moline, Ill.
8	Neil Stueck, Stupp Brothers Bridge & Iron Co., Box 24, Lemay P. O., St. Louis 23, Mo.
9	W. H. Greer, assistant district manager, Southwestern Laboratories, 1103 Chartres, Houston, Tex.
10	Dean Tillotson, president, Aweco Supply Co., Tucson, Ariz.
11	Darwin Christofferson, welding engineer, Chicago Bridge & Iron Co., 3676 S. 3000 West, Salt Lake City, Utah

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In accordance with National By-Laws, ballots will be mailed to all Society members on or before Dec. 26, 1955. Balloting will close on Jan. 26, 1956. Election results will be published in the May 1956 issue of The Welding Journal. Elected nominees will officially assume office on June 1, 1956.

THINGS YOU SHOULD KNOW

• On Thursday, October 20th, during the Society's National Fall Technical Meeting at Philadelphia, in the Bellevue-Stratford Hotel, the AWS 1954–56 Board of Directors held their fourth meeting. It was a very well attended meeting. Of the 31 Board Members, 21 participated, including 8 of our 11 District Directors.

• The Secretary presented an interim report covering the period Nov. 4, 1954 to Oct. 19, 1955. It was a compilation of those reports received from the District Directors covering the activities of and progress attained in each of their Districts during the past year, of the work conducted by the Society's Standing and Special Committees, and a summary of the important actions of the Board of Directors and its Executive Committee and Technical Council during the same period.

• A copy of the National Secretary's Interim Report has been mailed to the recorded Secretary of each AWS Section and we suggest that it be reviewed at the Sections Executive Committee Meeting and the more important actions made known to the Sections' membership at an early regular meeting.

• The Board in Philadelphia, upon recommendations by the Technical Council, established the Special Committee on the Welding Handbook as a standing committee of the Society. That Committee is now being staffed by its Chairman, Past-President Fred L. Plummer, with Board approval, for immediately going to work on the Fourth Edition of the Welding Handbook.

The new Welding Handbook is going to be unique in that its pattern will be far different not only from that of past editions but from that of handbooks of other societies as well. Watch for a story in The Welding Journal on this new program. We know that you will not only be interested but that you will like what is to be done.

• A new Special Committee on Member Classes was appointed by the Board to examine our present membership classifications, study the various suggestions that have been received for changes—and for no changes—and see if they can come up with an answer that will satisfy the majority. If you have any ideas on this, put them in a letter addressed to—"Chairman of the Member Classes Committee, c/o the Society's Secretary." He will pass them on to the Committee promptly.

• The organization of a new AWS Section at Shreveport, La., was approved by the Board. It will be known as the Shreveport Section and its official organization date was Nov. 1, 1955. We welcome the new Shreveport Section to our evergrowing fold and we wish them every success.

• President Joe Humberstone, who is also Chairman of the Board of Directors, proposed that the Society seek ways and means for sponsoring a program aimed at promoting welding processes and welded fabrication; a program which will serve all phases of welding and all concerned in the welding industry; one that will not impair the relationship of AWS and the welding industry with other cooperating organizations and industries; one which will enlist the sponsorship and support of at least a substantial majority of the welding machine, equipment, supplies and products manufacturers; and one which will engage the fruitful interest of fabricators, specifiers and potential users of welding. On the day previous, this proposal was presented to the Society's Manufacturers' Committee—this group indicated a favorable reaction and suggested that a nominal sum be expended by the Society for making a survey and preparing a program presentation for submission to all concerned, including the welding machine, equipment, supplies and products manufacturers. The Chairman of the Society's Publicity Committee, "Hank" Clauser, roughly outlined possible programs, and the Board then approved proceeding with the initial survey and presentation program by his Committee.

• Approval was given by the Board to the expansion of the South Florida Section boundaries so that a Division of that Section could be organized at Tampa, Fla.

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The National Fall Meeting in Phila-

delphia has been covered in detail in a previous section of the JOURNAL; so, we just will say that it was a fine affair and that it was a real pleasure to meet so many of our members who came from far and near, and to voice our sincerest appreciation to our hosts, the Philadelphia AWS Section, whose Officers and Members did such a fine job.

• Altogether, considering the fact that it is going through building and facility reconstruction, the Bellevue-Stratford Hotel, at Philadelphia, gave us very good service. There were some occasional mix-ups, but the new management did its best to adjust each one at once. Courtesy was the order of business, a much welcome improvement over the SOCIETY's experience in 1952.

• We never fully know the talents of some of our folks until something develops which, without planning, brings them to the fore. At the National Dinner on Monday Night, where we were we were honored to have with us the SOCIETY's Founder, Dr. Comfort Adams and his charming daughter-in-law, Mrs. Adams, as well as Miss Margaret M. Kelly, AWS Secretary Emeritus, our Chairman of the Convention Committee, Walter Goerg, who acted as Master of Ceremonies, really "outdid" himself. Several times, he just threw away the script and happily wandered into an entertaining "ad-lib" zone which was not only very good, but also most welcome. Then, genial Ed Dato, Past National Membership Chairman, thoroughly enlivened the presentation of the National Membership Awards, by some choice appropo comments when he and the winners struggled with those tonlike bronze membership plaques while waiting for a cameraman to first get his box into perfect focus and then find that he had no film—or no something. Orchids—big ones—to Walter Goerg and Ed Dato.

• Well, we near the end of this dialogue—a relief to you, we know—but, before leaving, we are reminded about what was nearly another end.

Just about 10 days before the Fall Meeting, your Secretary was in one fine haze—and daze—getting every (he hoped) last minute detail lined up; committee reports, his report and 157 varieties of activities. Right at the end he realized he was still short a *biography* from one of the award winners. So, thoroughly efficient (?), he called in "Girl Friday" to take a telegram. And, he dictates "Take a wire to Mr.—(blank-blank): Say—'where is your *obituary*? Must have at once.'" Confident and unquestioning girl as she is, she comes back "To where will I address it? Heaven or ——?" You know, I wasn't *quite* sure.

JOSEPH MAGRATH, *Secretary*

TAC TALKS

A Report of the AWS Committee on Piping and Tubing

by V. T. Malcolm

In May 1948 the important AWS Committee on Piping and Tubing was reorganized; and on its reorganization the Committee found itself faced with a tremendous volume of work in order to prepare satisfactory practices for the standardization committees and Code bodies.

In the reorganization of this Committee some of the most outstanding engineers engaged in power generation, oil refining and the chemical industry were invited to accept membership. Their acceptance resulted in a smoothly functioning committee that has gained national prominence through its work on the development of recommended practices, such as:

1. Butt Welding Ends for Pipe Valves and Fittings.
2. Postweld Treatment of Austenitic Steel Weldments.
3. Repair Welding of Cast-Iron Pipe, Valves and Fittings.
4. Interruption of Heat-Treatment Cycles for Low Chromium-Molybdenum Steel Piping Materials.
5. Report on the Welding of Austenitic Stainless Steels.

All of these recommendations have now been published and certainly are a great aid to industries engaged in weld fabrication.

(*1*) *Butt Welding Ends for Pipe, Valves and Fittings.* A short summary of this standard shows that it is equally applicable to other piping components which are connected into the piping system by butt welding. It includes requirements for re-entrant shapes for heavy wall ends, welding bevel profiles, inside contours for joints made with or without backing rings, and machining dimensions with their tolerances. These recommendations have been accepted by MSS, and Pipe Fabrication Institute and are now published as a tentative standard by ASA B16.

(*2*) *Postweld Treatment of Austenitic Steel Weldments.* This standard covers the thermal stress relief of austenitic chromium-nickel stainless-steel welds. It is a necessary addition to Code practices because improper thermal treatment after welding of austenitic stainless steels may seriously affect the service characteristics of weldments, and the definition of thermal treatment had to be modified accordingly. This recommendation has been published as AWS Recommended Practice D10.1–53T.

(*3*) *Repair Welding of Cast-Iron Pipe, Valves and Fittings.* The extent to which iron castings are used in industry makes it inevitable that occasions arise when repairs by welding are urgently needed; and the fact that iron castings can be successfully welded if certain essential practices are employed has resulted in repair welding being used for the correction of imperfections in new castings produced in the foundry and for the repair of installed castings which developed defects in service. There had never been a properly established practice for this type of repair work for piping components so the Committee developed this recommended practice. This was published by the AWS as Recommended Practice D10.2–54T and it presents in useful form information relative to several repair methods which may be used in the repair of cast-iron pipe, valves and fittings. This practice has been accepted by other technical committees and as such was urgently needed.

(*4*) *Interruption of Heat-Treatment Cycles for Low Chromium-Molybdenum Steel Piping Materials.* The problems considered herein are related only to interruption or lowering of the preheat or interpass temperature before applying the postwelding heat treatment, either before or after completion of the welded joint. No attempt has been made to recommend minimum preheat temperatures or optimum postweld heat-treatment temperatures, since these temperatures are properly specified in procedure specifications. This recommended practice, recently published, therefore, only includes the effects of interrupting the welding—postheating cycle and the consequences of interruption in its effect on the weldment.

(*5*) *Report on the Welding of Austenitic Stainless Steels.* In taking the Committee's scope into consideration there was little doubt that we needed more predictability of ductility and freedom from cracking in the stainless steels. It was, therefore, important that we establish practices and proce-

V. T. Malcolm is Chairman, AWS Committee on Piping and Tubing; Director of Research, Chapman Valve Manufacturing Co.

dures for welding austenitic chromium-nickel stainless steels to improve the predictability of what may happen in the welding of piping by learning many of the characteristics of austenitic chromium-nickel stainless steels. This has been done in the Report on the Welding of Austenitic Stainless Steels which has just been published. The Committee report is so presented as to acquaint industry with an over-all picture of the welding of austenitic chromium-nickel stainless steels.

Because of the all-inclusive nature of our work we have been closely associated with other technical committees as ASA B16, ASA B31, ASME Boiler Code, Pipe Fabrication Institute, MSS, U. S. Navy, API, AGA, ASTM, and Edison Electric Institute; and all of these groups have liaison members on our Committee.

The cooperation between the various groups has been of great value and the source of considerable gratification, and it certainly has tended to eliminate much confusion on welding of piping and tubing.

Nelson Stud Welding Becomes a Sustaining Member

Nelson Stud Welding, Division of Gregory Industries, Inc., Lorain, Ohio, has recently become a Sustaining Member of the AMERICAN WELDING SOCIETY. This company manufactures the Nelson stud welder and flux-filled studs and fasteners used with the equipment. Nelson stud welding is an arc welding process whereby the establishment of the arc, determination of the welding time, and the final plunging home of the stud or fastener is controlled automatically. The equipment, available as a portable hand tool or as a stationary production unit, is used throughout the metalworking and construction industries to speed production, reduce costs and improve product quality.

R. C. Singleton has been appointed Sustaining Member Representative.

W. J. Barrett Elected President of Engineers

The United Engineering Trustees, Inc., recently elected Walter J. Barrett as president for the ensuing year. Mr. Barrett is well known in engineering circles, being treasurer and a director of the American Institute of Electrical Engineers which he represents on the Board of UET. He is also a director of Engineers Joint Council, and is electrical coordination engineer of the New Jersey Bell Telephone Co., Newark.

United Engineering Trustees, Inc., was incorporated in 1904 for the chartered purpose of the advancement of the engineering arts and sciences in all their branches and to maintain a free public engineering library. The Corporation owns and operates the Engineering Societies Building on W. 39th St., which was a gift from Andrew Carnegie as "a union home for the engineers." It also owns and operates the Engineering Societies Library, one of the most important free public engineering libraries in the world, as well as the Engineering Foundation for organized "research in science and engineering and the advancement in any other manner of the profession of engineering, and the good of mankind." It acts in a fiduciary capacity for a large number of joint activities of the major engineering societies.

Other officers elected by UET include Willis F. Thompson and A. B. Kinzel, vice-presidents; Joseph L. Kopf, treasurer George W. Burpee, assistant treasurer, and John H. R. Arms, secretary and general manager.

EMPLOYMENT SERVICE BULLETIN

Position Vacant

V-329. Welding Research Engineer. B.S. degree in engineering; 0-3 years' industrial experience. Type of engineering course immaterial providing it has included a good background of physical science. Better than average scholastic record essential. This is a permanent position with a well-established firm in their modern laboratory located in North Central New Jersey. Position offers opportunity to develop and learn through contact with men who have achieved stature in their respective fields. Advancement commensurate with ability. Well-established retirement, stock investment and group insurance plans available. Submit résumé of personal history, education, experience and salary requirements. Replies held confidential.

Services Available

A-681. Shop Superintendent and Welding Engineer. Twenty years' experience in plant and instruction on all ferrous and nonferrous metals; also all known processes and procedures used today. Would like to locate in Great Lakes area, Calumet region or Southern Michigan in small fabricating plant as superintendent or welding engineer; or as a welding consultant for an arc rod machine company having offices in this area (trouble shooting, etc.). Can furnish the best references.

SECTION MEETINGS

Dear Sir:

It has been my pleasure to have had the opportunity of talking to numerous sections of the AMERICAN WELDING SOCIETY in the past. I have noticed a growing tendency on the part of some of the sections—particularly the larger ones—to dilute the technical nature of the meetings.

The use of "coffee speakers" or movies of an entertainment nature or of a technical nature, unrelated to the meeting, tend to distract from the technical speaker's presentation. It appears to me that the object of the AMERICAN WELDING SOCIETY and its sections is to advance the knowledge and understanding of welding. It is a sad commentary on our SOCIETY if supplementary entertainment is necessary in order to assure good attendance at the section meetings.

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Of course, our sections have a social function also, but this can best be performed by the use of a different type of meeting at which there is no technical speaker—such as "Ladies' Nights" or "Past-Chairman Nights."

Yours very truly,

R. W. TUTHILL, *Supervisor*
Welding Process Engineering
General Electric Company
York, Penna.

1955 Annual Assembly of the IIW

The International Institute of Welding, on the invitation of the Swiss member societies, held its eighth annual assembly in Zurich from Sept. 11 to 17, 1955. Some 720 persons attended the assembly, of whom about 530 were delegates appointed to represent member countries on the Governing Council and Commissions of the Institute.

No previous assembly has been so well attended but, notwithstanding the large number of participants, the organization of the congress ran very smoothly, thanks to the excellent arrangements made by the Swiss Reception Committee.

Meetings of the Governing Council of the IIW were held at the beginning and end of the assembly and four whole days were devoted to meetings of the 15 Commissions and their drafting committees. In addition, delegates had the opportunity of seeing technical films produced in a number of different member countries and of attending a public session at which were discussed papers on the general theme "Welding in the Construction of Dams, Sluice Gates, Penstocks, Water and Steam Turbines and Electrical Equipment for Power Stations."

During the assembly generous hospitality was offered to all members of the assembly by different Swiss organizations including the Swiss member societies of the IIW which invited participants to a banquet.

In the week following the assembly many delegates remained in Switzerland to participate in works visits organized in different parts of the country by the Swiss Reception Committee.

Among the matters on which the Governing Council of the IIW took decisions during its two meetings in Zurich were the following:

1. Professor Riess (Germany) was elected vice-president of the IIW for a term of three years in succession to G. Hansen (Denmark).

2. The following societies were elected to membership: Mines Branch, Department of Mines and Technical Surveys—Canada; Canadian Welding Bureau; and National Committee for Welding of the Science Council of Japan.

3. Dr. H. G. Taylor, Director of the British Welding Research Assn., was appointed Chairman of Commission III—Resistance Welding, in succession to R. W. Ayers (United Kingdom), resigned.

4. L. André, Deputy Chief of the Swedish Labour Inspectorate, was appointed Chairman of Commission VIII—Hygiene and Safety, in succession to Professor S. Forssman (Sweden), resigned.

5. The Governing Council accepted invitations from the Spanish and German delegations to hold the annual assemblies of the IIW in Madrid and Essen in 1956 and 1957, respectively.

All the Commissions met in Zurich, the majority of them holding four meetings of three hours each. The reports of the Chairmen on the work undertaken during these meetings will be available shortly for publication. These reports will give details of the resolutions of a technical character resulting from the work of the Commissions which were submitted to the Governing Council at its closing meeting and of the relevant decisions of the Council.

Thirty-four papers which had been printed and distributed before the assembly were presented by four rapporteurs and discussed. The papers were divided into four groups dealing with penstocks (6 papers), hydraulic and steam turbines (8 papers), dam construction (6 papers) and electrical equipment for power stations, maintenance and metallurgical problems (14 papers).

The president of the IIW is Dr. Howard Biers one of the official delegates from the United States representing the AMERICAN WELDING SOCIETY. The United States was also very ably represented at the meetings of Commission IX on Behavior of Metals Subjected to Welding by David Brown, vice president of the American Bureau of Shipping and Dr. R. D. Stout, professor of metallurgy at Lehigh University.

The meetings in 1956 of the IIW will be held in Madrid, Spain, July 2nd to 9th.

OHIO STATE ALUMNI MEET IN PHILADELPHIA

On Tuesday evening, October 18th, a number of Ohio State University alumni, associated with the AMERICAN WELDING SOCIETY Student Chapter, met at the Bellevue-Stratford Hotel in Philadelphia, during the AWS National Fall Meeting, to get better acquainted with one another and to renew student-day friendships. Professor Roy B. McCauley, Chairman of Department of Welding Engineering, spoke briefly on department changes and aims.

The group expressed the wish to include in this gathering any Ohio State University alumni who attend the AWS meetings. They felt that all present would profit from the mutual sharing of a common interest. The major limitation here seemed to be the ability to locate these people to facilitate their invitation. The best idea seemed to be to contact companies having welding interest and invite their OSU alumni to these meetings.

Shown above are those who attended the 1955 Ohio State University AWS Student Chapter Alumni Dinner Meeting in Philadelphia on October 18th. *(Standing, left to right)* Dan Bellware, Walt Edwards, Dave Kelker, Dick Odell, Bob Kreiger, Tom Broughton, Bob Wright, Charlie Davis. *(Seated, left to right)* Frank Baysinger, Boy Myers, Roy McCauley, Jack Keyte, John Rudy. Also present was Ray Stitt who took the above picture

GOODERHAM ADDRESSES TORONTO SECTION OF CANADIAN WELDING SOCIETY

R. M. Gooderham, Director of the Canadian Welding Bureau delivered an interesting talk to an audience of over a hundred members and guests attending the first meeting of the 1955–56 season of the Toronto Chapter—Canadian Welding Society, on Oct. 3, 1955.

Mr. Gooderham, who is also a member of the AMERICAN WELDING SOCIETY, spoke of his experiences in Europe as a member of Mission No. 250 of OEEC (Organization for European Economic Co-operation). This mission started in Paris, France, and continued on through 11 different countries. He elaborated on two significant statements "Europe excels in welded design" and "America excels in methods of production and operating efficiency." He explains that labor being less costly, and steel more expensive, Europeans spent more time in designing.

Europe in general has little automatic welding equipment, but great strides are being made in this direction. When Europeans do make an automatic setup, according to Mr. Gooderham, they do a good job.

A series of colored slides were shown illustrating European testing equipment, and welding procedures both in the shop and in the field.

R. M. Gooderham *(second from right)* shows a portable recorder used on his trip to Europe. *(Left to right)* George J. Foster, Secretary, Toronto Chapter; E. Buscombe, Reception Committee Chairman; Charlie Reid, 2nd Vice-Chairman; B. Gregg, Chairman; R. M. Gooderham, Director, Canadian Welding Bureau; J. Brown, Past-Chairman

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Section News and Events

as reported to Catherine O'Leary

QUIZ THE EXPERTS

Fort Wayne, Ind.—Forty-five members of the *Anthony Wayne* Section were present at a dinner meeting held at the Hobby Ranch House in Fort Wayne on September 29th. Following the dinner a four-member panel composed of K. Zimmerman, Carl Gabby, George Laws and Harry Johnson answered 16 of the best questions submitted by the entire membership. The panel quiz discussion was given a grade of 72 by the judges—James McLain, Ernest Albert and Carl Cary. Moderator was D. B. Rice.

PLANT VISIT

Phoenix, Ariz.—Members of the *Arizona* Section visited the plant of the Allison Steel Manufacturing Co. on September 21st. They were shown new methods of welding and miscellaneous fabricating processes.

WELDING PROCEDURE

Phoenix, Ariz.—Joseph Marden of Eutectic Welding Alloys Corp., Los Angeles, Calif., gave an excellent talk on welding procedure at the October 19th dinner meeting of the *Arizona* Section held at the Hotel Westward Ho. Mr. Marden's talk was given at a nontechnical level and was very helpful from the welder's standpoint. Mr. Marden also showed a 20-min film on methods of welding and soldering different metals together. In addition, he gave an actual demonstration on what was shown in the film.

MARDEN ADDRESSES ARIZONA SECTION

Shown at the October 19th meeting of the Arizona Section are (*left to right*): Charlie Fogwell, past-chairman; Bob Sferra, secretary; Bill Fischer, chairman; and Jonathan Marden, Eutectic Welding Alloys Corp., guest speaker

GAS-SHIELDED WELDING

Birmingham, Ala.—The use of carbon dioxide as a gas shielding medium for consumable electrode welding of mild steel was discussed by R. W. Tuthill [illegible], Supervisor, Welding Process Engineering, General Electric Co., at the October 11th dinner meeting of the *Birmingham* Section held at Hooper's Cafe. Seventy-five members and guests were present.

GOLF OUTING

Chicago, Ill.—On October 1st, the *Chicago* Section held its 14th Annual Golf Outing at the Nordic Hills County Club at Itasca, Ill.

Over two hundred members and guests had a most enjoyable time. The weather was ideal, the meals were delicious, and the prizes numerous. Judging by the reaction of the crowd, a good time was had by all.

FLAWS IN THE WELD METALS

Cleveland, Ohio.—"Evaluation and

SECTION MEETING CALENDAR

JANUARY 6th

LEHIGH VALLEY Section. Bethlehem, Pa. "Battle of the Cities." Chairman—L. J. McGeady.

JANUARY 9th

NORTH CENTRAL OHIO Section. Marion. Dinner, movie, speaker, question and answer period.

NORTHWEST Section. The Covered Wagon, Minneapolis. "Submerged Arc and Twin Arc Application." Speaker to be announced.

JANUARY 10th

DAYTON Section. 8:00 P.M. Engineers Club, 112 E. Monument Ave., Dayton, Ohio. "Power Soures for Arc Welding," John H. Blankenbuehler, Design Engineer, Hobart Brothers Co.

JANUARY 11th

CLEVELAND Section. Manger Hotel. Dinner 6:30 P.M. Annual Executive Night. "Future of Welding," by J. F. Lincoln, president, Lincoln Electric Co.

JANUARY 12th

SAGINAW VALLEY Section. Dinner, 7:15 P.M. High Life Inn, Saginaw, Mich. "Weld Fabrication and Flame Straightening."

IOWA-ILLINOIS Section. 7:30 P.M. American Legion Club, Moline, Ill. "Fundamentals of Resistance Welding," by A. Leslie Pfeil, Universal Welder Corp.

JANUARY 17th

NEW JERSEY Section. Essex House, Newark, N. J. Dinner 6:30 P.M. Meeting 8:00 P.M. "Ship Building."

HARTFORD Section. Villa Maria, Glastonbury, Conn. International Nickel Co. speaker

JANUARY 18th

PITTSBURGH Section. Auditorium, Mellon Institute of Industrial Research, Oakland. "C-Omatic" Process—Automatic Welding with Carbon-Dioxide Gas, by Robert J. Keller, Assistant Director of Research, A. O. Smith Corp., Milwaukee, Wis.

JANUARY 20th

MARYLAND Section. Engineers Club, 6 W. Fayette St., Baltimore. "Automotive Welding," by John Randall, Ford Motor Co.

JANUARY 24th

NORTHWESTERN PENNSYLVANIA Section. Erie, Pa. "Welding Metallurgy," by G. E. Claussen, Metals Research Laboratory, Linde Air Products, Niagara Falls, N. Y.

JANUARY 26th

MADISON Section. Eagles Club, Madison, Wis. "Prevention and Control of Distortion in Welding," by LaMotte Grover, Air Reduction, Inc.

Editors Note: Notices to be published in any one given issue must reach Journal office prior to the first of the preceding month. Give full information concerning time, place, topic and speaker for meeting.

Causes of Flaws in Weld Metals" was the subject of a technical talk given by R. P. Sopher, assistant chief, Metal Joining Division, Battelle Memorial Institute, at the October 12th meeting of the *Cleveland* Section. Mr. Sopher gave the reasons for weld cracking and the different types of flaws. Considerable time was spent on welding of 4340 carbon steel. Test proved that steel with the less amount of sulfur had less cracks.

FUTURE OF WELDING

Cleveland, Ohio.—The *Cleveland* Section January meeting to be held on January 11th will be the Annual Executive Night. Main speaker will be J. F. Lincoln MWS, president of the Lincoln Electric Co. His subject will be "Future of Welding."

A large attendance is anticipated for this meeting. Naturally, everyone who is associated with welding will want to hear what the future of welding holds for them.

The Cleveland Section is honored to have Mr. Lincoln address them on this most vital subject.

AUTOMATIC WELDING

Denver, Colo.—An attendance of thirty members and guests were present at the October 11th dinner meeting of the *Colorado* Section held in the Festival Room of the Oxford Hotel. In lieu of a coffee speaker, a film entitled "Detour to Wonderland" was shown through the courtesy of the Denver & Rio Grande Railroad Co.

The main speaker for the evening was B. R. Russell of Airline Welding & Engineering of Hawthorne, Calif. His subject was "Automatic Fixtures and Procedures for Automatic Welding." Mr. Russell explained how titanium, in any thickness from a thousandth of an inch to 1 in. thick, can be welded by automatic means. The speaker illustrated his talk with a film presentation.

AUTOMATION

Dayton, Ohio.—A joint meeting of the *Dayton* Section with the Cincinnati Section was held on October 11th at the Dayton Engineers Club. The meeting opened with a movie by the Dow Co. on recovery of magnesium from sea water.

Speakers at the technical meeting were Boyd V. Giesey, general manager, and Robert H. Blair, chief electrical engineer of Resistance Welder Corp. They introduced their subject "Automation" as incorporating material handling, labor savings and quality improvements, the achievement of which also requires clear-cut motions, precise locator accuracy and precise part accuracy. Discussion and illustrations of this subject was conducted by Mr. Giesey through five short movies of automated equipment, including two assembly machines and several appliance, automotive and strip steel welding machines.

ANTHONY WAYNE SECTION HOLDS QUIZ-THE-EXPERTS NIGHT

Dinner preceded the quizzing of the experts. Here's one corner of the Dining Room of Hobby Ranch House where meeting was held

The members of the panel of experts were (left to right) K. Zimmerman, Carl Gabby, George Laws and Harry Johnson

PROGRAM

Dayton, Ohio.—Program of meetings of the *Dayton* Section for the remainder of the season is given below.

January 10—"Power Sources for Arc Welding," John H. Blankenbuehler, design engineer, Hobart Brothers Co.

February 14th—"Basic Problems of Welding Metallurgy," Austin Hiller, manager, Product Planning, General Electric Co.

March 13th—New Resistance Welding Techniques, Panel Discussion, Carl Bertsche, *chairman*.

April 10th—"Hard Facing," Howard S. Avery, research metallurgist, American Brake Shoe Co.

May 8th—Welding Quiz Program, Dinner Meeting with other AWS Sections.

June 12th—Annual Picnic.

All meetings will be held at 8 P.M. in the Dayton Engineers Club, 112 E. Monument Ave.

AIRCRAFT RESISTANCE WELDING

Detroit, Mich.—Sixty-five members of the *Detroit* Section met on October 14th for the regular monthly dinner meeting. Coffee speaker was Foster Winter of the J. L. Hudson Co. who discussed the St. Lawrence Seaway, a subject which, with the forthcoming bridge across the Straits of Mackinac, represents two long-term physical changes in this area that are certain to bring economic growth and benefits.

The technical meeting covered the general subject of resistance welding in the aircraft industry and was attended by 140 members and guests. Two speakers were heard at this session. Gordon Parks MWS, Solar Aircraft Co.'s chief engineer, covered the engineering-manufacturing side of

DETROIT SECTION HEARS PARKS AND WOODMANCY

Guest speakers P. G. Parks (*left*) and G. Woodmancy (*right*) pictured with Wm. H. Smith, 1st Vice-Chairman of the Detroit Section, at the Oct. 14, 1955 meeting. Their talks dealt with welding in aircraft industry

the aircraft industry, and Glenn Woodmancy AWS, research engineer of Boeing Airplane Co., Wichita Division, presented a paper on "Oscillograph Instruments in Spot Welding Quality Control and Maintenance."

RECTIFIER WELDERS

Appleton, Wis.—The October 21st meeting of the *Fox Valley* Section was held at the Elks Club in Appleton. Speaker G. K. Willecke of the Miller Electric Mfg. Co., spoke on Rectifiers for Welding. Mr. Willecke's talk covered the basic differences between motor generator, transformer and rectifier type welders with emphasis on construction, efficiency and use.

He explained the method of manufacturing selenium packs in detail. This part of the talk was illustrated by blackboard sketches and actual packs. He discussed in detail the electrical phenomena that makes a rectifier work.

CASTINGS VERSUS WELDMENTS

Hartford, Conn.—The *Hartford* Section's second meeting of the fall season took place on October 11th at the Villa Maria Restaurant in Glastonbury.

Technical speaker was Sidney Low AWS, Supervising Engineer of the research and development laboratory at Chapman Valve Mfg. Co., Indian Orchard, Mass. Mr. Low gave an illustrated talk on the subject of "Castings Versus Weldments" and went on to show that often by using a casting and a weldment better results are obtained than by the use of one alone.

ELECTION OF OFFICERS

Davenport, Iowa.—The *Iowa-Illinois* Section announces the election of the following officers for 1955–56: *Chairman*—Kenneth McDowell; *1st Vice-Chairman*, Glen O. Fruit; *2nd Vice-Chairman*, Ernest Escobar; *Treasurer*, Claire Morrow; *Chairman, Membership Committee*, W. LeRoy Palmer; *Chairman, Program Committee*, Frank Garver; *Technical Representative*, W. LeRoy Palmer; *Secretary*, Vaughn A. Dodge, 1515 34th St., Moline, Ill.

AUTOMATIC WELDING

Kansas City, Mo.—The *Kansas City* Section met at Fred Harvey's Pine Room at the Union Station for their October 13th meeting and enjoyed a very interesting and informative talk by B. R. Russell, owner of Airline Welding and Engineering, Hawthorne, Calif.

Mr. Russell's subject was "Automatic Welding Fixtures and Procedures" and in conjunction with this talk he presented numerous colored three-dimensional slides, which gave an unusual depth of perception, illustrating the special welding tooling that they have created, both during construction and after completion. He also showed a movie which pictured in color the numerous types of welding fixtures in operation using the gas metal-arc and gas tungsten-arc and submerged-arc welding processes on titanium aluminum and other various alloys. He had brought along samples of his welding on titanium which he passed around to the various interested members and guests.

WELDING OF STAINLESS STEEL

Hollis, L. I.—Sixty members of the *Long Island* Section attended the October 13th meeting held at Patricia Murphy's Candlelight Restaurant. Speaker was Harry F. Reid, Jr., of the McKay Co., York, Pa. Mr. Reid discussed the problems encountered in welding various classifications of stainless steels, stainless steel electrodes and electrode manufacturing processes were described.

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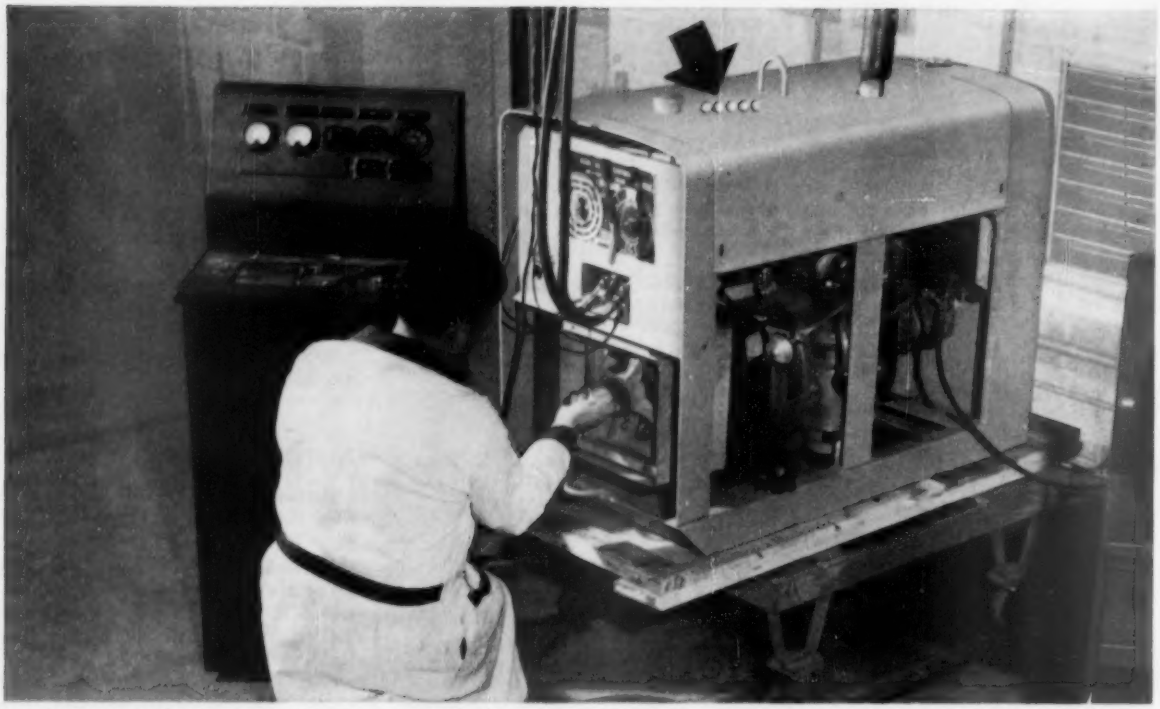

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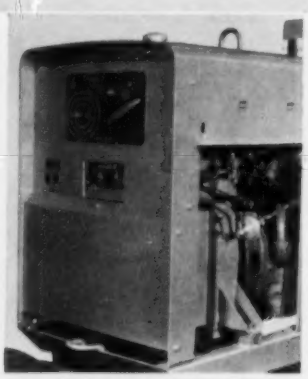

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Six months of rigorous in-the-field testing by 18 pipeline welding operators has already proved that the new G-E engine-drive welder has that extra punch needed for top performance in job shops, on construction, and similar welding operations.

Only the new G-E welder has so many features that assure superior welding. With "rugged simplicity" built in, the G-E welder has fewer parts, sturdier construction for longer life.

Check below to see how this welder compares with other make welders, feature by feature. Then make your own test.

For more information, write for bulletin GEC-1333, Section 714-1, General Electric Company, Schenectady 5, New York, or contact your nearby G-E Welding Distributor. He's listed in the yellow pages of your phone book. And ask him also about General Electric's new special electrodes for construction—W-610A and W-710A. 714-1

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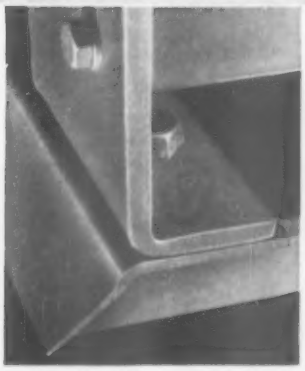
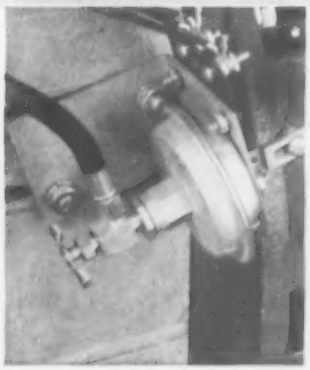
CONSTANT PRESSURE BRUSH SPRINGS—New feature eliminates need for adjustment.



HEAVY-GAUGE METAL THROUGHOUT—16-gauge canopy, 3/16-in. channels, 1/4-in. cross bars withstand rough field conditions.



OVER 12-HOUR OPERATION—New slowdown control and 17-gallon tank give more than one shift operation on a tank of gas.

SPRING-WOUND TRAILER AXLE—New construction of axle reduces side sway and weaving for easier towing, better tracking.

✓	✓	✓	✓
	✓	✓	

WELDING ZIRCONIUM

Los Angeles, Calif.—The October meeting of the Aircraft and Rocketry Panel of the *Los Angeles* Section was held on October 6th at Swally's Cafe. Speaker was Bruce Baird, Research Engineer, North American Aviation Inc., Downey, Calif. "Fusion Welding Zirconium for a Nuclear Reactor" was the subject of Mr. Baird's talk. This lecture covered the details, the development, and conclusion of the research and development program initiated by North American; also, a bit about nuclear reactors.

INERT-ARC WELDING

Los Angeles, Calif.—The *Los Angeles* Section held its regular October meeting on the 20th at Swally's Cafe.

The speaker for the evening was R. F. Kluck, service engineer for the Linde Air Products Co., who discussed and summarized the various inert-arc welding techniques presently being used by industry to eliminate the use of backing rings in butt-welded joints of piping. Mr. Kluck referred to inert arc techniques that have practically replaced all metal arc and gas processes for root pass welding of pressure piping of chrome-moly and the 300 series stainless steel varieties.

Mr. Kluck used a unique method of presentation. His formal talk had previously been recorded and the recording was played back over the loud speaker system. After the formal presentation, Mr. Kluck answered numerous questions. Copies of Mr. Kluck's paper were available for those present to use for future reference. Representatives from national and local piping fabricators and the two major electric power producers in Southern California were present.

Two door prizes provided by Pacific Metals Co. were awarded to people attending the meeting.

As a token of the Los Angeles Section's appreciation for Mr. Kluck's presentation, he was presented with a pen desk set.

One hundred and twenty-five members and guests were present at the dinner and meeting.

SELECTION OF ELECTRODES

Baltimore Md.—The October meeting of the *Maryland* Section came off on schedule at the Engineers Club, Baltimore on October 21st.

The technical speaker for the evening was H. A. Stanick assistant field welding engineer for Chicago Bridge and Iron Co. Mr. Stanick used as his subject "The Selection of Electrodes" which was supplemented with two movies.

The after-dinner talk was presented by William A. Jordan of the Maryland State Roads Commission. He used as his subject "Baltimore Harbor—River Crossing." He used slides showing plans and elevations and cross sections of the twin tube construction under the Patapsco River bed.

Both talks were well presented and exceedingly interesting. The attendance was good.

The subject for January 20 meeting will be "Automotive Welding" which will be presented by John Randall of the Ford Motor Co.

WELDING ELECTRODES

Milwaukee Wis.—A. Clemens, Jr. AWS, director, research and welding engineering, Arcrods Corp., Sparrows Point, Md., was the technical speaker at the September 23rd meeting of the *Milwaukee* Section held at the Ambassador Hotel. In Mr. Clemens' talk on "Mild-Steel, Low-Hydrogen, and Low-Alloy Arc Welding Electrodes," he told how to select the proper electrode for the job and the characteristics of the deposited metal.

After dinner, a talk was given by Fred M. Roberts, president, Sport Diver Corp., Milwaukee.

BRITTLE FRACTURES

Newark N. J.—The *New Jersey* Section held their regular monthly dinner at the Essex House Hotel, on October 11th.

Before 35 members and guests, the speaker of the evening, S. R. Kleppe of Esso Research and Engineering Co. gave a very interesting talk describing a test program developed to simulate field conditions of a failure in a welded oil storage tank erected at Fawley, England. Illustrating with slides, Mr. Kleppe gave a complete review of the test procedure, application of the test result and their effect on the current evaluation of notch sensitivity in steel. Considerable interest was shown in an exhibit of a 1-in. section taken from the tank at the point of failure.

NONDESTRUCTIVE TESTS

New York, N. Y.—"Nondestructive testing procedures employed in the construction of the Aircraft Carrier

KLEPPE ADDRESSES NEW JERSEY SECTION ON BRITTLE FRACTURES

This is a portion of the large crowd that was present to hear S. R. Kleppe's talk on Brittle Fracture Studies

Member and guests shown examining a 1-in. section removed from tank at point of failure

Section Chairman J. E. Riley presents Mr. Kleppe with a memento for the fine job done at the meeting

DREXEL PRESIDENT ADDRESSES PHILADELPHIA SECTION

Dr. James Creese, president of Drexel Institute of Technology, is shown addressing members of the Philadelphia Section on the occasion of Educational Night held on September 19th. AWS President "Joe" Humberstone is seated (partially hidden from view) at Dr. Creese's right. National Secretary "Joe" Magrath and Technical Secretary "Si" Greenberg were also present.

U.S.S. Saratoga," was the subject of the paper presented to the *New York* Section on Oct. 11, 1955. John L. Cahill AWS, welding engineer for the New York Naval Shipyards, Brooklyn, N. Y., was the speaker.

All methods used in connection with the nondestructive testing were explained by the speaker, including X-ray and gamma-ray as well as magnetic particle tests, and tests by reflectoscopes. Considering that this carrier has a tremendous high-pressure power plant, and approximately four acres of flight deck, the magnitude of the job can be visualized.

The talk was illustrated by a series of slides which gave the audience a clear picture of the operations involved. The presentation by Mr. Cahill was excellent.

The reason for this particular topic was the fact that this was a joint meeting between the Society of Naval Architects and the AMERICAN WELDING SOCIETY. As a consequence the lecture room was filled to capacity.

In addition to the main lecture, entertainment in a lighter vein was provided immediately after the dinner.

The meeting was held at Schwartz Restaurant, 54 Broad St., New York, N. Y.

PLANT TOUR

Mansfield, Ohio.—Sixty-one members and guests of the *North Central Ohio* Section thoroughly enjoyed a visit to the Empire Steel Corp.'s hot strip mill on October 7th. Dinner was held prior to the tour at the Mansfield Leland Hotel after which L. F. McCaffrey, assistant general superintendent of Empire, outlined the steel making process, the hot strip mill and Empire Steel's position in the steel business. It was interesting to know that right in this area is one of the largest producers of electrical sheet in the entire industry. Those who made the tour were impressed by the complete mechanization of the mill and by learning how a red hot billet soon becomes a coil of sheet metal.

WELDING METALLURGY

Oak Ridge, Tenn.—Dr. G. E. Claussen AWS, Metals Research Laboratory, Niagara Falls, N. Y., was the guest speaker at the September 19th meeting of the *Northeast Tennessee* Section held at the Knights of Columbus Hall. Dr. Claussen presented a very interesting lecture on "Welding Metallurgy of Steel." His talk was illustrated by slides, movies and sample welds.

PROGRAM OF MEETINGS

Schenectady, N. Y.—The following is the meeting schedule of the *Northern New York* Section for the balance of the scheduled (1956) season.

February 2nd—"Advantage & Disadvantage of Contact Electrodes." Speaker: A. Clemens, Jr. (Airco), Place: Panetta's Restaurant, Menands, N. Y.

March 1st—"RPI Research Programs." Speakers: RPI Personnel Place: Rensselaer Polytechnic Institute, Troy, N. Y.

April 12th—"The Welding of Plastics." Speaker: Dr. J. A. Neuman (American Agile). Place: Stanley Club, Pittsfield, Mass.

May 3rd—Ladies' Night, Annual meeting. Arrangements to be announced later.

PRODUCTION WELDING

Erie, Pa.—The first meeting of the season of the *Northwestern Pennsylvania* Section was held on Tuesday September 27th at the General Electric Co.'s community center. Refreshments and dinner were served prior to the technical meeting.

Technical speaker was Anthony J. Pandjiris, president of the Pandjiris Weldment Co. Mr. Pandjiris' subject was "Position All Three—The Man, The Work, The Automatic Head."

CONTACT ELECTRODES

Erie, Pa.—The October dinner meeting of the *Northwestern Pennsylvania* Section was held on October 25th at the Kenyon Hotel. Speaker at the meeting was Donald B. Howard AWS, No. 2 District Director, of the ACF Industries, Inc. His subject was "Evaluating Contact Electrodes for Production Use."

PANEL DISCUSSION

Philadelphia, Pa.—The regular monthly Panel Discussion Meeting of the *Philadelphia* Section was held on Friday evening, October 7th, at the Engineer's Club. The subject was "Maintenance Welding in Plant and Shop." It was a three-part discussion, as follows:

J. N. Childs, chief engineer of Metalweld, Inc., Philadelphia, Pa., gave a very interesting talk on the problems encountered in specialized jobbing and maintenance welding from the jobbing standpoint.

F. J. O'Malley, welding supervisor, Maintenance Shops of the Philadelphia Electric Co., Philadelphia, Pa., discussed the problems involved in keeping a power plant running. This involved the welding and repair of alloy high-pressure piping and other unusual maintenance jobs.

P. G. Nelson, supervisory metallurgist, Budd Co., Philadelphia, Pa., discussed the problems in tool and die repairs and the problems peculiar to keeping a large press department operating at a high rate of production. He discussed the various air-harden-

ACCO products

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1. Packaged to fit your particular requirements

2. A wide range of analyses to fit a particular job

3. Greatest convenience — you can buy from local stocks

There is every reason why you should look to PAGE for your automatic welding wire needs. For PAGE not only manufactures wire in an extremely wide range of analyses, but packages them in a variety of ways for the most complete protection and convenience in handling and stocking. PAGE Distributors throughout the country carry stocks — this means savings for you, in ordering time and in inventory investment.

Shown above are some of the handy ways PAGE Automatic Welding Wire is packaged...There are lightweight, durable Leverpaks, which provide perfect protection against coil distortion or wire corrosion. They're easily opened and resealed, roll easily, stack perfectly and take a minimum of floor space.

There are single and pallet-mounted (1,000 lb., 2,000 lb., 3,000 lb.) coils, each wrapped in waterproofed paper and held secure by steel strapping; thread-wound, 25-pound reels to fit popular machines; also, coils in individual cardboard cartons, available singly or palletized for handling by fork-lift truck.

Page Offers 26 Analyses in Automatic Welding Wire

In order to provide you with *exactly* the correct automatic welding wire for your specific requirements—no matter how "special" or "different" they may be—PAGE offers no less than 26 different analyses from which to choose. These "cover the waterfront" of applications: heavy automatic submerged arc...light manual submerged arc ...inert gas manual and automatic, tungsten or metal arc.

Carbon Steel • Any carbon from Armco (.025 max.) to high carbon (.90—1.10). All standard AISI analyses in between.

Low Alloys • All the most popular welding grades

Stainless • AISI grade. Other types on request

Following is a list of the *26 analyses* in which PAGE Automatic Welding Wire is readily available:

Page A-S-Armco	Page A-S-110
Page A-S-6	Page A-S-15
Page A-S-10	Page A-S-15-MO
Page A-S-17	Page A-S-3½-Nickel
Page A-S-20	Page A-S-6150
Page A-S-65	Page A-S-4130
Page NAX-9115	
Page-Allegheny A-S-Type 304	
Page-Allegheny A-S-Type 308	
Page-Allegheny A-S-Type 308 ELC	
Page-Allegheny A-S-Type 309	
Page-Allegheny A-S-Type 310	
Page-Allegheny A-S-Type 316	
Page-Allegheny A-S-Type 316 ELC	
Page-Allegheny A-S-Type 347	
Page-Allegheny A-S-Type 348	
Page-Allegheny A-S-Type 410	
Page-Allegheny A-S-Type 420	
Page-Allegheny A-S-Type 430	
Page-Allegheny A-S-Type 502	

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• The *right* electrodes and the *right* rods for every welding job! That is what you must have for perfect operation—and that is what you can expect from the wide range offered by PAGE. Choose what you need from this complete line:

Gas Welding Rods

Armco Gas (GB-45)	Page Armco
Mild Steel (GA-50)	C Gas
Low Alloy (GA & GB-60)	Hi-Tensile M
3½% Nickel (GB-65)	3½% Nickel
.55—.65 Carbon	Medium Carbon
.90—1.10 Carbon	High Carbon
Manganese Bronze	Manganese Bronze
Naval Bronze	Naval Bronze
Stainless Steel	According to AWS analysis

Any Page A-S Automatic Grade in 36" Lengths

Bare Electrodes

Armco	Page Armco
Low Carbon	Page "CE"
.13—.18 Carbon	Page "B"
.55—.65 Carbon	Medium Carbon
.90—1.10 Carbon	High Carbon

Metal Spray Wire

Armco	Page Armco
.10 Carbon	#10
.28 Carbon	#25
.40 Carbon	#40
.60 Carbon	#60
.80 Carbon	#80
1.00 Carbon	#100
3½% Nickel	3½% Nickel
Manganese Bronze	Manganese Bronze
Naval Bronze	Naval Bronze
Stainless Steel Metal Spray	According to AWS Analysis

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PAGE Distributors carry ample stocks from which your requirements can be filled without delay or inconvenience to you. This handy service not only saves you time in getting what you need, but makes it unnecessary for you to make a sizeable investment in inventory. Thus, your nearby PAGE Distributor is able to make double savings for you—a saving in time and a saving in actual dollars.

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ing, water- and oil-hardening steels and electrodes that are required for this type of maintenance work.

The presentations were followed by a very interesting discussion period. The many questions asked were well answered by the above speakers.

PLANT TOUR

Weirton, W. Va.—The September meeting of the *Pittsburgh* Section held on September 28th was in the nature of a plant visit to the Weirton Steel Co. in Weirton, W. Va. Due to last-minute changes in original plans, the 40 members and guests were shown only a general view of a blast furnace and the operation of a small welding (maintenance) shop. Considerable disappointment was expressed when members and guests could not be given access to new welded buildings under construction.

MAINTENANCE WELDING

Pittsburgh, Pa.—The October dinner meeting of the *Pittsburgh* Section was held on October 28th in the Hunt Room of the Hotel Webster Hall. The technical meeting was held in the auditorium of the Mellon Institute of Industrial Research in Oakland. Technical speaker was Theodore Gaynor of the Bethlehem Steel Corp., Johnstown, Pa. His interesting subject was on "How Welding Slashes Steel Mill Maintenance Costs." Slides were used to illustrate Mr. Gaynor's talk. Steel mill maintenance welding utilizes most of the different welding processes and use of commercially available alloys and applications in all production operations. Maintenance welding has become an important tool in keeping a steel mill in operating condition and the welder has become an indispensable member of the maintenance and repair crews.

SCHEDULE OF MEETINGS

Pittsburgh Pa.—The following is a schedule of meetings, subjects and speakers for the remainder of the season (1956) of the *Pittsburgh* Section. All meetings will be held in the auditorium of the Mellon Institute of Industrial Research, Oakland, with the exception of the April meeting which will be held in the Webster Hall Hotel.

January 18th—"C-Omatic" Process—Automatic Welding with Carbon-Dioxide Gas, by Robert J. Keller, Assistant Director of Research, A. O. Smith Corp., Milwaukee, Wis.

February 15th—"The Welding Research Council," by Dr. Robert D. Stout, Professor of Metallurgy, Lehigh University, Bethlehem, Pa.

March 21st—"Current Techniques for the Production of Reliable Welds in Steel Structures," a joint meeting with the Pittsburgh Chapter of the American Society of Civil Engineers and the Civil Engineering Section of the Engineers Society of Western Pennsylvania.

April 27th—Nineteenth Annual Tri-State Ladies' Night and Dinner—Entertainment, Door Prizes, Music, Guest Speaker. Georgian Room, Webster Hall Hotel. No afternoon technical session.

SILVER-BRAZING ALLOYS

Seattle Wash.—The *Puget Sound* Section held its October dinner meeting at the Engineer's Club on October 13th.

Speaker at the meeting was Jack Lafferty, West Coast service engineer for Handy and Harman. Mr. Lafferty's subject was on "Fundamentals and Characteristics of Silver Brazing Alloys." A film was shown on various types of brazing equipment and techniques used with production brazing. With natural gas coming into this area, special interest was shown in equipment that utilizes this fuel gas for brazing equipment.

IRON-POWDER ELECTRODES

Richmond, Va.—The first meeting of the *Richmond* Section for the 1955–56 season was held in the Monticello Room of Holloway House on October 20th.

Technical speaker was Harry F. Reid, Jr. of the McKay Co. In a most timely talk, Mr. Reid traced the origin and development of the various types of iron-powder electrodes both in Europe and the U. S.; discussed their merits and disadvantages, and, with the aid of slides, pointed out the factors which govern the usability of these types of electrodes by the welding industry today.

At the conclusion of his talk, Mr. Reid answered several questions from the floor.

WELDING OF SPHERES

Saginaw, Mich.—The *Saginaw Valley* Section held its October dinner meeting at the High Life Inn on October 13th. Perry C. Arnold of the Chicago Bridge & Iron Co. presented movies and gave a talk on the erection

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welding and special problems on the large 225-ft sphere which his company erected in New York. Mr. Arnold's talk also covered the results of some destructive testing of the new Carrilloy T-1 steel.

NONDESTRUCTIVE TESTING

San Francisco, Calif.—The September 26th meeting of the *San Francisco* Section held at the Engineers' Club, was devoted to the subject of "Nondestructive Testing of Welds."

A. M. Croswell AWS, welding engineer of the Bechtel Corp., San Francisco, presented his portion of the program on the importance of radiography as a tool toward improving quality of base materials and weld deposits. Mr. Croswell remarked on how radiography permits us to look inside the weld to detect internal flaws such as cracks, slag inclusions and gas pockets.

One of the most important factors pointed out by him is the accuracy and integrity of the technician or inspector interpreting the film. Responsibilities of these men are greatly magnified when considering the potential hazard to public life, property and investments necessary to construct power plants, refineries and high pressure gas transmission lines.

Kermit Skeie, regional district manager of the Magnaflux Corp., Los Angeles, discussed the systems of magnetic particle inspection such as Dychek, penetrants, ultrasonic, and Zyglo black-light methods.

Each of these systems were qualified as to their use and the importance of the inspector to properly interpret the indications from each method to determine what type of discontinuities are being indicated.

Both of the speakers were able to contribute a great deal of valuable information on these methods of inspection based on actual field practice.

EDUCATIONAL MOVIES

San Jose, Calif.—The October dinner meeting of the *Santa Clara Valley* Section was held on October 25th in the Hawaiian Gardens. A record attendance of 134 turned out for this meeting. The program consisted of two educational movies. The first, on "The Prevention and Control of Distortion in Arc Welding" was presented by Merril F. Yale, welding engineer for the Lincoln Electric Co. This sound color motion picture, produced by Walt Disney Studios in Hollywood, simply and dramatically explains why and how metals expand and contract when they are heated and cooled, and how the problem of preventing or controlling distortion can be solved. The second movie on "Welding Advances with Aluminum" was presented by Ronald H. Skow, welding engineer for the Linde Air Products Co. This is a sound, color-motion picture, produced by the Aluminum Company of America, which features and explains the latest information on welding aluminum alloys including gas tungsten-arc welding and the new gas metal-arc welding process.

A coffee talk by Joseph A. Garcia, foreman, Be-Ge Manufacturing Co., Gilroy, Calif., gave some highlights of the operation at Be-Ge.

FIRST TECHNICAL MEETING

Shreveport, La.—The *Shreveport* Section held its first technical meeting at Kappans Restaurant at the Greater Municipal Airport, October 22nd, with an attendance of 65 members and guests.

J. Robert Welsh, president of Southwestern Gas and Electric Co. and representative of Shreveport's Industrial Committee for the Chamber of Commerce, was the coffee speaker. Mr. Welsh gave a very interesting talk on the objectives of the Industrial Committee and how they planned to bring more industries to this area.

The technical speaker was H. H. Olson AWS, specification engineer for Sheffield Steel Co. of Houston, Tex. Mr. Olson's talk was on requirements of steel for pressure vessels, and was enjoyed by all the members.

The Shreveport Section was recently organized by J. L. York, *Chairman;* J. Kelley, *1st Vice-Chairman;* E. B. Reeves, *2nd Vice-Chairman;* Alton Henderson, *Secretary;* Byron Doggett, *Committee;* Hollis Green, *Treasurer;* Joe LaBarbera, *Committee;* C. E. Russell, *Committee;* and Ed Hotchkiss, *Committee.* The Section is represented by members from 24 industries from the Shreveport area and is increasing daily as the organizing of this Section is still under way. Forty officers and committeemen have been elected or appointed and are active in the membership drive to increase the membership to 100 before the first of the year. The officers have extended their services to the Industrial Committee of the Shreveport Chamber of Commerce to talk to their groups when needed.

The officers would like to express their appreciation to "Joe" Magrath, "Frank" Mooney and District Director J. B. Davis for their assistance in the organizational work of this Section, and the committee at headquarters who gave their approval in making this Section possible.

IRON-POWDER ELECTRODES

Syracuse, N. Y.—Dinner and technical meeting of the *Syracuse* Section was held in the Hiawatha Room of the Hotel Onondaga on October 12th. Coffee speaker was F. C. McCarthy whose efforts in helping retarded children led to his being honored by having the Frank C. McCarthy School in Syracuse named after him.

Mr. McCarthy's talk was centered particularly around the problems faced by parents of mentally retarded children.

Technical speaker was Richard K. Lee, vice-president in charge of research for the Alloy Rods Co., York, Pa., who gave an interesting and very informative discussion on "All-Position Welding with Iron-Powder Low-Hydrogen Electrodes."

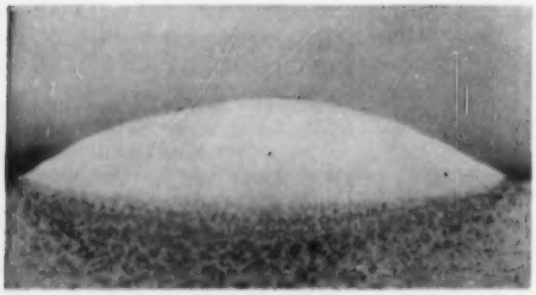
Mr. Lee pointed out that the problem of storage was greatly reduced inasmuch as after a short time in air the regular low-hydrogen rods pick up moisture and have to be rebaked before they are usable, whereas the iron-powder low-hydrogen electrodes

$3800 SAVED! When a transmission housing broke on a [illegible] Navy Ship, operations were suspended. The replacement cost of $3800 and a 6-week delay were saved with the Xyron 2-25 weldment illustrated. Careful tests proved the weld was completely free of cracks and porosity.

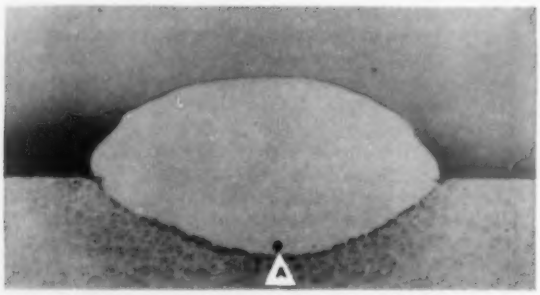
Xyron 2-25 has been proven ideal for [illegible] repair of such applications such as cracked motor blocks, machine bases, gears and gear housings. Xyron 2-25 makes it possible for the welder to lay in large volumes of filler metal, run long beads without excessive heat build-up in the base metal. All the advantages of Eutectic's low heat input welding process has been brought to the arc welding of cast iron.

$20,000 SAVED! When this $20,000 cast iron condenser crashed to the ground, the manufacturer expected to replace it completely or at best to stand an expensive and lengthy repair job. But, with Xyron 2-25 the entire repair was successfully completed in less than 100 hours. The repair was found to be entirely free of cracks and "leakers" and was accomplished without warping or embrittlement of the base metal. The welders performing this job reported amazement with the faster, **non-stop** welding possible with this new Eutectic electrode.

Announcing a New, Revolutionary, crack-free Eutectic's XYRON 2-25 outperforms any



This photomacrograph reveals one of the secrets of Xyron 2-25's superiority over the usual nickel electrodes. Notice the shallow uniform penetration. The smooth tapered shoulders of this deposit minimize stress formations and aid slag removal, eliminate cracks and "leakers." The extreme fluidity and wetting action of Xyron 2-25 eliminates the need for a lot of electrode manipulation.



This photomacrograph of **conventional** nickel electrode deposit shows how built-in stresses are caused, resulting in dangerous cracking in service. This electrode gives only a deep, localized penetration with excessive build-up and lack of wash. This deposit is not even machinable at point A. Xyron 2-25 deposits are superior in machinability at every point.

WANT MORE PROOF?

Your local Eutectic District Engineer is ready to show you, in your own shop, with your own materials, that Xyron 2-25 will out-perform any nickel cast iron electrode you may now be using. He'll show you how Xyron 2-25 will let you make better welds at amazing savings in time and labor. Contact your local Eutectic District Engineer today or use the coupon to arrange an appointment.

Comparative Welding Characteristics of Cast Iron Rods and Electrodes

new

CHARACTERISTICS	FEATURES	FILLER METAL COMPOSITION: ELECTRIC ARC: Xyron 2-25	ELECTRIC ARC: Nickel	ELECTRIC ARC: Nickel-Iron	ELECTRIC ARC: Nickel-Copper	OXY-ACETYLENE: Cast Iron	OXY-ACETYLENE: "Bronze"	REMARKS
PREPARATION	VERSATILITY (Base Metal Variations)	Superior (1)	Excellent (2)	Excellent (2)	Limited (3)	Excellent	Excellent	1. Suitable for all types, including alloys, Meehanite, Ni-Resist, etc. 2. Alloying elements (or high phosphorus content) may cause cracking or poor weld. 3. More acceptable to checking due to composition variations.
PREPARATION	ACTIVITY (Pre-cleaning)	Superior (1)	Excellent	Excellent	Good	Superior	Varied (2)	1. Ability to wet dirty and oxidized surfaces without pre-cleaning. 2. Surface must be chipped or sand blasted. Improper cleaning or technique results in unbonded areas.
PREPARATION	PRE HEATING	No (1)	200 F	200 F	200 F	1500 F 2000 F	1300 F 1500 F	1. Usually not used except when maximum machinability is required.
DEPOSITION	ALL POSITION WORK	Excellent	Superior	Good	Excellent	Poor (1)	Good	1. Requires skill and experience to a great extent.
DEPOSITION	CRACK SENSITIVITY	Superior	Good	Excellent	Poor (1)	Superior (2)	Superior	1. Subject to cross-checking due to hot shortness. 2. Assuming cooling rate is uniform. Subject to hot cracking when exposed to draft or cool air currents.
DEPOSITION	LEAK PROOFNESS	Superior	Fair	Fair	Poor	Poor	Poor	
DEPOSITION	SLAG (FLUX) REMOVAL	Superior	Excellent	Excellent	Good	Very difficult (1)	Difficult (1)	1. Generally requires time-consuming mechanical action or special equipment (sand or shot blasting, etc.)
DEPOSITION	DEPOSIT APPEARANCE	Superior	Excellent	Good	Good (1)	Varied (2)	Varied (2)	1. Generally produces deposits of uneven surface (mottled). 2. Entirely dependent on individual skill.
DEPOSITION	COLOR MATCH	Excellent	Fair	Excellent	Fair (1)	Superior	Poor	1. Subject to copper segregation.
DEPOSITION	TENSILE STRENGTH (JOINT)	Superior	Excellent	Excellent	Good	Varied (1)	Varied (1)	1. Varies with joint design and amount of reinforcement padding.
DEPOSITION	HEAT RESISTANCE	Excellent	Excellent	Excellent	Fair (1)	Superior	Poor	1. Subject to hot shortness and segregation.
DEPOSITION	MACHINABILITY	Excellent	Superior	Good	Excellent	Superior (1)	Superior	1. Cooling rate must be retarded to prevent the formation of hard spots.

strontium-aluminum bearing electrode ... conventional nickel electrode for cast iron

perfect for all types of gray and ductile cast iron including "Meehanite", "Ni-Resist" and joining cast iron to steel

Here's proof of the superiority of Eutectic's new Xyron 2-25. Just study the comparison chart above and you'll see that Xyron 2-25 gives you everything you want for faster, better welding. The case histories shown are typical of the reports by users all over the country, in extensive tests.

And, Xyron 2-25 is not just another conventional nickel alloy electrode. Its new strontium-aluminum formulation gives Xyron 2-25 higher weld quality and strength by purging the molten filler metal from harmful sulfur and sulphides, purifying it from oxide inclusions and improving the electrode's fluidity. All types of cast iron alloys such as Meehanite, Ni-Resist, and others, cast iron joined to steel, even old, dirty, and oxidized surfaces can be welded without preheating when you use Xyron 2-25. Not only does Xyron 2-25 save you time, but it also minimizes or eliminates the danger of warping, stress or embrittlement of the base metals.

The crack-free feature of this new electrode makes it ideal for the newest metals in the cast iron field. There is no weldable application for cast iron for which Xyron 2-25 cannot be recommended. It is the electrode every weldor has been waiting for.

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can be exposed to the air for much longer periods of time without detrimental effect.

Another point which he made was that when welding in the vertical position with the low-hydrogen iron-powder electrode, less porosity in the weld is encountered because the whipping technique used for standard electrodes is not required.

PROGRESS IN WELDING

Washington, D. C.—Clarence E. Jackson, manager, Welding Research Group, Metals Research Laboratories, Niagara Falls, N. Y., was the guest speaker at the technical session of the past-chairmen's Night held on September 27th by the *Washington* Section. Mr. Jackson's subject "Progress in Welding," reviewed new developments in the field of welding and traced the growth of welding and the future growth of joining metals. Mr. Jackson was one of the members of an OEEC Mission which recently visited 40 welding plants in eleven European countries.

WELDING CLINIC

Washington D. C.—An Inert-Gas Arc-Welding Clinic and Symposium was held on Tuesday, October 25th, from 9:00 A.M. to 4:00 P.M., by the *Washington* Section. The Welding Clinic and Demonstrations were held at the Southern Oxygen Co.'s Plant in Bladensburg, Md. The dinner and evening program from 6:15 P.M. to 10:00 P.M. were held at the Hamilton Hotel in Washington, D. C. Two hundred and twenty-five members and guests attended.

Live demonstrations of latest equipment and processes were displayed and operated by representatives of the Aluminum Company of America, General Electric Co. and Linde Air Products Co.

A Symposium was held in the evening with W. F. Ruehl of the Southern Oxygen Co. as Moderator. Panel members were J. Warden Cunningham, of the Air Reduction Co., on the subject of "Versatility of Inert-Gas Metal-Arc Welding"; J. S. McKenzie, Linde Air Products Co., on the subject of "New Development of Inert Arc Welding and Apparatus"; and R. D. Mann, General Electric Co., on the subject of "Carbon Dioxide Welding of Mild Steel." Each panel member spoke for approximately fifteen minutes on his subject and then the meeting was thrown open to questions from the floor for about one hour. The Section has received numerous commendations on the Welding Clinic and Panel Discussion.

TECHNICAL MOVIES

Worcester Mass.—The first meeting of the 1955–56 season of the *Worcester* Section was held on October 3rd at the Hickory House. A social hour and dinner preceded the meeting.

The program of the evening consisted of two very excellent U. S. Steel Corp. pictures. "The Waiting Harvest," a treatise on chemical developments in the recovery of the many useful articles obtained as by-products from bituminous coal.

The second picture "Iron Ore from Cerro Bolivar," carried this fabulous iron ore discovery from the exploration stage in the Venezuela jungles right through to the delivery of the ore at the Fairless Works near Trenton, N. J.

Russell Best of the American Steel and Wire Co., Worcester, made a short explanatory speech at the conclusion of the pictures.

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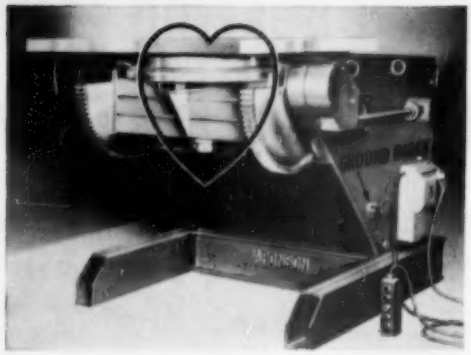

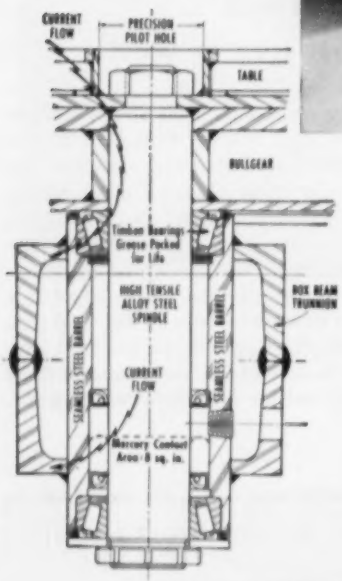

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Jones, E. C. (C)
Morhain, Clarence V. (C)
Wyse, Jack (C)

BIRMINGHAM

Vann, Robert W. (C)

BOSTON

Acker, Harold G. (B)
Adams, Clyde M. (B)
Cilley, Kenneth D. (B)
Faulk, Richard C. (A)
Janosky, John W. (C)
Walsh, John F. (C)

CHATTANOOGA

Lewis, Joe (C)

CHICAGO

Blake, Terance B. (C)
Butler, S. (B)
Coffey, David (B)
Ecker, Gerson S. (C)
Fagerstrom, Stanley J. (B)
Frandsen, G. (B)
Gehlert, Fred A. (C)
Harbison, Charles (B)
Lynch, Frank (C)
Stoffer, Charles W. (C)
Swift, Albert H. (C)
Wickersham, William (B)
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Vannier, Russell B)

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Jelm, Charles R. (B)
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Kerls, Edward W. (C)
Mascarello, John R. (B)

COLUMBUS

Esherick, Peter (C)
Traxler, Frederick E. (C)

DALLAS

Adams, Frederick S. (C)

DETROIT

Colyer, Jack D. (B)
Gibson, James (B)
Hupp, Charles J. (B)
Krause, Scott F. (B)
Liljren, Paul (C)
Marksian, Harley (C)
Mohr, Ray (C)
Richmond, Robert H. (C)
Sallen, Robert D. (B)
Singbiel, Richard (C)
Starke, C. H. (C)

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Anderson, Jerome G. (C)
Dorn, Richard (B)
Diedrich, Hugo (C)
Eckholm, Clarence W. (C)
Grant, Robert (C)
Hall, Russel, E. (C)
Hansen, Charles (B)
Jacklin, Gordon H. (C)
Jenkins, Francis (B)
Kurtz, L. W. (B)
Mueller, Edward H. (B)
Loepes, Gerald (B)
Stewart, E. H. (B)
Thurner, Harold (B)
Wieseckel, Clarence M. (C)

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Morrone, James J. (B)

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Scott, Corley S. (C)
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Phelps, T. S. (C)
Ruckman, James R. (B)

INDIANA

Hilburt, Robert J. (C)
Hollingsworth, T. E. (C)
Walkosak, Robert (C)

LONG ISLAND

Argeropoulos, Byron A. (C)
Yates, Seymour (B)

LONG BEACH

Garfield, Gerald (C)

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Bohne, Del R. (C)
Brockman, William M. (C)
Haythorne, P. A. (C)
Gills, John D. (B)
Rheinhardt, Edward H. (C)
Sharp, Carroll E. (B)
Starz, Victor H. (C)
Yoder, George A. (C)

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England, Charles I. (B)

MADISON

Detter, Paul (C)
Foss, Bernard C)
Gossen, Edward (C)
Johnson, Donald B. (B)
Riddle, Lloyd (C)
Schuetz, Michael (C)
Simpson, Loren C. (B)
Waldvogel, E. A. (B)

MAHONING VALLEY

Keppler, R. S. (C)

MARYLAND

Burrier, Charles H. (C)
Danzer, Charles M., Jr. (B)
Miller, William M., Jr. C)
Tyminski, Edmund S. (C)

MICHIANA

Edwardson, R. T. (C)

MILWAUKEE

Dollak, Joseph D. (C)
Mueller, Bernhard O. (C)
Phillips, E. P. (C)
Steveling, Robert C. (C)
Von Rohr, E. Jeane (B)
Woelm, F. C. (C)
Young, Otis H. (B)

NEW JERSEY

Bracken, Victor P. (C)
Chase, David O. (C)
Dippler, John H., Jr. (B)
Elliott, Harry B. (C)
LeGrand, Pierre E. (B)
Komleski, Edward A. (B)
Merriman, R. H. (C)
Minard, Lister C. (B)
Muller, Edward J. (C)
Skiba, Edward J. (B)
Spence, Douglas E. (B)
Wrigley, George E. (B)
Yanckek, George F. (B)

NEW ORLEANS

Horn, Robert L. (B)
Ruie, R. L. (B)
Wallace, L. G. (C)

NEW YORK

Block, Norman (B)
Donnelly, John F. (B)
Fleischil, Bernard W. (B)
Kniffen, Allen T. (B)
Morrisey, John J. (B)

NIAGARA FRONTIER

Held, Clarence C. (C)
Livingstone, Ross A. (B)
Reinhardt, Walter (C)
Smith, Clyde W. (B)

NORTH CENTRAL OHIO

Bates, Homer J. (C)
Dawson, Wayne K. (C)
Lown, Bernie (C)
Smith, Evoitt W. (C)

NORTHEAST TENNESSEE

Richardson, L. (C)
Troutman, Thomas G. (B)

NORTHERN NEW YORK

Edgerton, Collin (C)
Elliott, Clarence (C)
Newton, Garth R. (B)
Thompson, Ernest G. (D)
Sluzas, Victor A. (B)

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Larson, Fredolph G. (B)
Lenxmeier, Leon M. (C)
Linton, William G. (C)
Peterson, Leroy C. (C)
Reiss, Donald E. (B)
Smith, Udal S. (B)
Stubenberg, R. W. (B)
Ziegler, Karl L. (C)

NORTHWESTERN PENNSYLVANIA

Cohn, Werner C. (C)
Ramsey, Clayton S. (C)

OKLAHOMA CITY

Razien, Abe (B)

OLEAN-BRADFORD

Fabian, Francis G., Jr. (B)

PASCAGOULA

Walker, Arnold A. (B)

PEORIA

Wright, Dale (C)

PHILADELPHIA

Babchuk, Walter (C)
Cain, Frank J., Jr. (C)
Cassin, Eugene P. (C)
Fleming, T. C. (C)

Girini, J. R. (C)
Holloway, Ralph L. (B)
Lazar, Valentine J. (B)
Levering, W. C. (B)
Long, Theodore R. (B)
Michalsky, William B. (B)
Noller, Christian, Jr. (B)
Nuss, William M. (C)
O'Connor, James P. (C)

PITTSBURGH

Dawes, James C. (B)
Gilson, William G. (B)
Kaltenhauser, Robert H. (C)
Newman, Dale C. (C)
Salvaggio, George J. (B)
Willett, Wallace D. (C)

PORTLAND

McReynolds, Sterling P. (B)

RICHMOND

Bowman, L. R. (C)
Nielsen, Peer D. (C)

PUGET SOUND

Hazzard, Lyle B. (B)

ROCHESTER

White, Paul L. (C)

SAGINAW VALLEY

Carolan, Keith M. (B)
Davis, Alfred F. (C)
Garrison, Roger K. (C)
Mueller, Donald W. (C)

ST. LOUIS

Gandolfo, Vito (B)
Heinicke, Otto F. (B)
Holz, Frank (B)
Mercer, Virgil E. (B)

SALT LAKE CITY

Ahleen, Wayne R. (C)
Bentley, Curtis K. (C)
Christiansen, Ray S. (B)
Gayer, Elmer L. (B)
Roberts, Mrs. Paul (C)

SAN FRANCISCO

Bennett, Lloyd (C)
Clark, Samuel H. (C)
Howard, Herbert (C)
McKnelly, Frank (C)

SANTA CLARA VALLEY

Barker, Earl E. (B)
Camp, Leslie J. (B)
Hoopes, J. W. (C)
Reiswig, Albert (C)
Zacharenkd, Vladimir S. (C)

SOUTH FLORIDA

Chastain, John R. (C)
Feller, Alfred C. (B)
Edward, John W. (B)
McCall, C. H., Jr. (B)
Rees, E. V. (B)

SYRACUSE

Kiena, Paul P. (B)

TRI-CITIES

Broadfoot, Carl E. (C)

WASHINGTON, D. C

Felbeck, David F. (C)

WESTERN MICHIGAN

Cook, Charles, Jr. (C)
Reed, Eugene M. (C)

YORK-CENTRAL PA.

Hill, Pierre F. (B)

NOT IN SECTIONS

Jalan, S. E. (B)
L'Esperance, O. L. (C)
Mitchell, C. C. (C)
Moran, Thomas F. (B)
Munnoch, J. (B)
Shaw, Odis W. (C)
Vilhalm, Vladimir (B)

Members Reclassified

During the month of October

CHICAGO

Matchett, Wendell E. (C to B)

CLEVELAND

Singleton, Robert C. (C to A)

DETROIT

Reynolds, Richard K. (C to B)
Smith, Joseph C. (C to B)

MARYLAND

Luter, E. B. (C to B)

NEW JERSEY

Hoffman, Henry L. (C to B)
Scordato, Vincent F. (C to B)
Yoczks, Stephen (C to B)

NORTHWESTERN PENNSYLVANIA

Boyer, Charles V. (C to B)

PHILADELPHIA

Scattergood, William K. (C to B)

PITTSBURGH

Golik, Mark A., Jr. (C to B)

SHREVEPORT

Hotchiss, Edgar N. (C to B)
La Barbera, Joe (C to B)
Lund, John (C to B)

SYRACUSE

Catter, Arthur K. (C to B)

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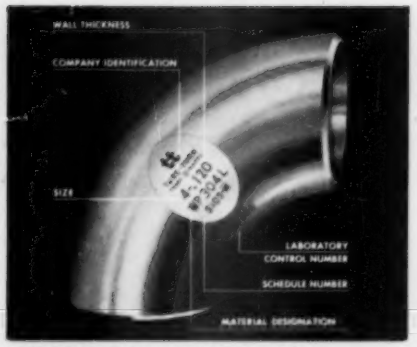

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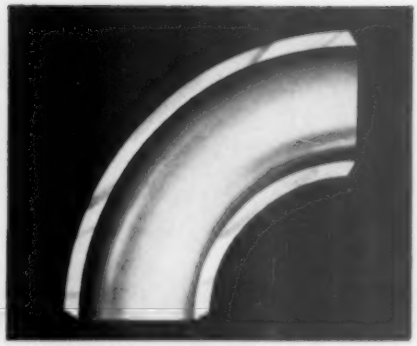

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NEWS of The Industry

New Distributor Appointed by Harnischfeger

Charles W. Krieg Co. of Newark, N. J. has been appointed a distributor of P&H welding products and electrodes, according to an announcement from the Harnischfeger Corp. at Milwaukee, Wis.

Charles W. Krieg Co. has sales and service offices at 48-60 Dickerson St. in Newark. The firm will represent Harnischfeger's line of P&H welding products and electrodes in the northern New Jersey area, and provide complete sales and service facilities.

Linde Experimental Facilities Expanded

Expansion of experimental facilities at the Speedway Laboratories located just outside of Indianapolis, Ind., has been announced by Linde Air Products Co., a division of Union Carbide and Carbon Corp. Work has begun and is expected to be completed next spring. The expansion program includes the conversion of a former factory building, located adjacent to 16th St. into a modern laboratory and office building.

The laboratory will have double the facilities now available for research and development activities. It will occupy a three-story, fireproof, air-conditioned building, having a floor space of 72,000 sq ft. The most up-to-date features of laboratory design are being incorporated. Construction and equipment costs will be approximately one and a half million dollars.

Their construction program will make possible new and broader projects for Linde in the fields of physics, chemistry and metallurgy. Investigations will include work in arc welding, acetylene chemistry and engineering, high-temperature chemistry, and flame-plating of metals.

Midwest Welding Conference Scheduled for February

The use of welding in two areas significant to the national defense—nuclear reactors and rocketry—will be considered at the Midwest Welding Conference February 1st and 2nd at Armour Research Foundation of Illinois Institute of Technology, Chicago.

Robert A. Noland, associate metallurgist, Argonne National Laboratory, Lemont, Ill., will talk on "Welding Problems in Nuclear Reactors" at 4 P.M., Thursday, February 2nd.

"Applications of Welding to Rocketry" will be discussed by Francis H. Stevenson, production engineer, Welding Department, Aerojet-General Corp., Sacramento, Calif., at 4 P.M., Wednesday, February 1st.

Twelve talks by researchers and users of welding processes are scheduled during the two-day meeting being sponsored by the Foundation and the Chicago section of the AMERICAN WELDING SOCIETY.

More than 200 persons interested in welding are expected to attend, according to Harry Schwartzbart, supervisor of welding research at the Foundation and chairman of the conference.

New Distributors for Amsco Welding Products

Five new distributors have recently been named by the American Manganese Steel Division of the American Brake Shoe Co. to handle sales of hard-facing alloys, manganese repointers and other welding products of that company. The recent development of an automatic welder, the Amsco Leader "550", for heavy industrial work, and a semi-automatic machine, the "MF" (magnetic flux), for smaller more mobile welding jobs, are reported as being among the reasons for this distributor expansion.

The new distributors who will handle these machines as well as the other Amsco welding products are the Interstate Welding Sales, Marinette, Wis.; Red Ball Supply, Inc., Oklahoma City, Okla.; Spencer's Industrial Sales & Service, Fallon, Nev.; Superior Oxygen Co., Houston, Tex.; and a new branch of the Williams Co. in Louisville, Ky.

PICTURED AT INTERNATIONAL STUD WELDING CONFERENCE

Dr. Ing. Busse of Peco-Verkaufsgesellschaft, Munich, who represented the German stud welding industry at the recent international stud welding conference in England, is shown here exhibiting a piece of light-gage sheet metal to which a large-diameter stud has been welded. Shown with him *(left to right)* are G. F. R. Berry, overseas commercial engineer for Crompton-Parkinson Ltd., and three Nelson Stud Welding executives who represented the United States and Canada. They are Maurice A. Enright, vice-president in charge of engineering; Robert S. Singleton, industrial sales manager, and George E. Gregory, president of Gregory Industries, Inc.

Modern Names Fausek Board Chairman

At a recent board of directors meeting the Modern Engineering Co., St. Louis, Mo., named A. J. Fausek chairman of the Board. Fausek was formerly president, a position he has held for many years.

Other officers are I. F. Fausek, president; Al V. Fausek, vice-president in charge of sales; Willis L. Reedy, vice-president in charge of production, and I. F. Fausek, Jr., secretary.

A. J. Fausek, company founder, has long been a nationally recognized leader in the Welding Industry. In 1952 he received the James Turner Moorehead Medal for his contributions to the design and development of oxy-acetylene equipment and the promotion of safety standards.

New Welding Equipment Firm is Formed

The formation of a new corporation, Industriline, Inc., for the manufacture and distribution of equipment for the welding and electrical transmission industries has been announced.

The company will offer new waterproof and shockproof cable connectors, strip heaters for preheating plates before welding, and new types of electrode holders. General offices of the new firm are at 441 Lexington Ave., New York 17, N. Y. The factory is located in Cincinnati, Ohio.

Principals of the new company are J. B. Nottingham, president, Robert Senior, vice-president, and Paul Savoca, secretary.

K-G Appoints New Distributors

The K-G Equipment Co., Inc., Allentown, Pa., manufacturers of precision welding and cutting equipment for industry and oxygen therapy equipment for the medical profession, announce the appointment of following distributors for their industrial equipment:

Gordon's Welding Supply Co., 32 Park St., Glens Falls, N. Y.; Joseph Hurwitz Co., 201 Kittaning St., Butler, Pa.; Temple Iron and Metal Co., 308 S. 14th St., Temple, Tex.; Travis Welding Supply Co., 4800 S. Lamar St., Dallas, 15, Tex.; Welding Sales Co., Boston Post Road, Orange, Conn.; and WP-RS Mars Co., 324 W. Michigan, Duluth, Minn.

Welding Machinery Lease Plan Offered

Progressive Welder Sales Co., 3070 E. Outer Drive, Detroit 34, Mich., has just completed arrangements for offering their complete line of equipment (standard or special design) on a lease basis.

According to J. F. McRoberts, vice-president and general manager of the company, this new plan will make it possible for many manufacturers to obtain immediate possession and use of the industry's finest resistance welding equipment designed specifically for their use, without impairing vital working capital.

Mr. McRoberts states that equipment leasing has proved highly successful for both manufacturer and user in other fields and a preliminary survey of the market indicates a popular demand for the plan.

Student Engineers Receive Awards

Lee Allgood of Grosse Pointe Woods, Mich., received the $1,250 first award in the 1955 competition for mechanical and structural designs by engineering students, sponsored annually by The James F. Lincoln Arc Welding Foundation of Cleveland. Allgood, as a senior at the University of Michigan, received the award for the design of a stamping die of welded construction, suitable for low quantity production, whose cost would be only 20% that of a conventionally made die. In honor of his achievement in this national competition, the Foundation gave the University of Michigan $1000 in scholarship funds.

The Lincoln Foundation, according to its chairman, Dr. E. E. Dreese, sponsors the annual competition to encourage engineering students to do some creative engineering in which they will make use of modern industrial techniques such as arc welding. Awards are made for student designs of machines or structures in which arc welding has made a significant improvement or cost reduction.

The designs submitted this year, says Dr. Dreese, indicate that our engineering schools are producing men with a good understanding of industrial problems and the need for constantly improving our industrial products. A total of $5000 was awarded to 57 engineers in 31 different schools; $2000 in scholarship funds were granted to schools honoring the main award winners.

The $1000 second award was received by Donald Croll of Franklin, Ohio, who, as a senior at the University of Cincinnati, designed a TV or radio transmission tower of welded tubular construction for a 22% weight saving.

Herman Greff of Detroit, Mich., at the University of Detroit, designed a welded shaper for which he received the $500 third award.

These awards were duplicated in scholarship funds donated by the Foundation to the schools in which the students were enrolled.

The Foundation has announced a similar competition for the 1955–56 school year, for which the rules are available from the Foundation in Cleveland, Ohio.

Kirkhof Manufacturing Joins RWMA

The Resistance Welder Manufacturers Assn. has announced that Kirkhof Manufacturing Corp. of Grand Rapids, Mich., has just become a member of that organization. The Membership now totals 16 manufacturers throughout the country.

New Ampco Weldrod Distributors Announced

The Weldrod Department of Ampco Metal, Inc., Milwaukee, Wis., has announced the appointment of three new exclusive, franchised distributors as follows: Buffalo Welding Supply Co., 37 E. Ferry St., Buffalo, N. Y.; Randall-Graw Co., 314 Jay St., LaCrosse, Wis.; and Hays Supply Co., 269–287 S. Front St., Memphis, Tenn.

Get the BEST for LESS
Get
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No. 1 Cast Iron Welding Flux
No. 2 Brazing Flux
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No. 8 "ABC" Sheet Aluminum Flux
No. 16 Silver Solder Paste Flux.

Send for complete Folder and Samples

Mfg. by
ANTI-BORAX COMPOUND CO. INC.
Fort Wayne 9, Indiana

WELDING ENGINEER

Expanding programs in welding, brazing and soldering have created an opening for a welding research engineer. This is an opportunity for diversified experience in joining. Salary commensurate with experience and training. Liberal employee benefits include generous tuition refunds for graduate study. Write:

Mr. T. E. DePinto
ARMOUR RESEARCH FOUNDATION
of Illinois Institute of Technology
10 West 35th St.
Chicago 16, Illinois

VICKERS® Controlarc DC Arc Welder Survives Punishing "Durability Test"

OVER
1,000,000
CYCLE
HIGH-SPEED
REPETITIVE
ARC TACK
TEST
EQUIVALENT
TO MORE THAN
TWO YEARS OF
CONTINUOUS
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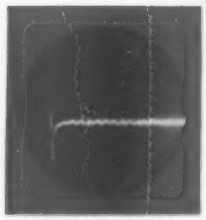

This unretouched oscilloscope photograph shows the voltage trace occurring when the arc was broken very quickly during the test, subjecting the CONTROLARC welder to severe abuse.

"How much punishment can the Vickers CONTROLARC DC Welder take?"

Vickers engineers decided to find out.

A 200-ampere CONTROLARC was subjected to a gruelling durability test. Every nine seconds the welder was charged with a six-second load of 250 amperes (50 amperes above rated capacity) at 27.5 volts. After 198,900 "makes" and "breaks" the load was boosted to 300 amperes at 27 volts. When the test was concluded the CONTROLARC had survived 1,004,522 of these charges, *and was still going strong*—with no apparent effect on any part of the welder. This test simulated arc tacking on production at 4 tacks continuously per minute on an 8-hour day basis for over two 300-day years.

For complete information about this rugged, dependable welder, write today for new bulletin.

VICKERS ELECTRIC DIVISION

VICKERS Inc. a unit of Sperry Rand Corporation

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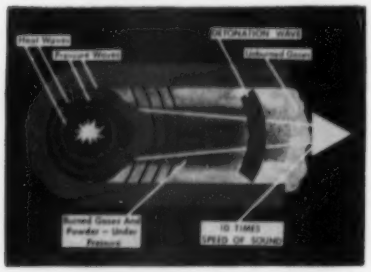
NEW PRODUCTS

Flame-Plating Process Announced by Linde

The availability of a new hard-surfacing process—Flame-Plating—has been announced by Linde Air Products Co., 30 E. 42nd St., New York City. The key to its operation is controlled detonation.



Flame-Plating is a surfacing method in which particles of tungsten carbide are literally blasted onto the surface of a workpiece. This is accomplished through the use of a specially constructed gun. Briefly, the gun consists of a barrel and a mechanism for loading precise quantities of tungsten carbide powder, acetylene and oxygen into the firing chamber. The tungsten carbide powder remains suspended in the explosive gases until a spark ignites the mixture producing heat and pressure waves. The confining shape of the barrel concentrates these waves in a small area producing a tremendous heat and pressure build-up. When the temperature reaches 6000° F, the heat waves begin to move faster than the pressure waves. This phenomenon is detonation.

The heat wave, also known as the detonation wave, rips through the gas and powder mixture at ten times the speed of sound, completely burning the gases and leaving behind a solid block of pressure in which the tungsten carbide powder is suspended. Pressure inside the barrel reaches 10,000 psi in three thousandths of a second. When the detonation wave leaves the muzzle of the gun, it is like pulling a gigantic cork out of a volcano. The detonation wave turns into a shock wave and dissipates into the air. The gases, jammed inside the barrel, burst out, carrying the tungsten carbide powder with them.

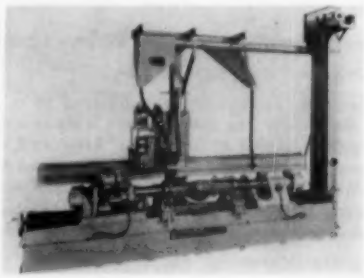
The particles of tungsten carbide become partially molten and are hurled at 9000 ft per sec at the workpiece. As blast after blast hits the surface of the part, the particles build up and fuse together until the desired thickness is obtained.

Although the temperature inside the gun barrel reaches 6000° F, the temperature of the workpiece seldom exceeds 400° F even when metals with extremely high melting points, such as tungsten carbide, are being deposited. This means that precision and semi-precision parts and tools can be flame-plated without risking changes in metallurgical properties or physical dimensions.

After flame-plating, the surface of the work piece looks and feels like fine emery paper. The coating is about 125 microinches rms, measured by the Brush Analyzer. The flame-plated part may be used in this condition or finished to various degrees of smoothness by standard carbide finishing methods. By grinding and lapping, the coating can be finished to less than 1 microinch rms.

Semiautomatic Shielded-Arc Welder

A new, general-purpose, semiautomatic, shielded-arc welding machine designed for producing circular welds on large round assemblies up to 13 ft



long is now available from the Expert Welding Machine Co., 17144 Mt. Elliott Ave., Detroit 12, Mich.

The machine has a 19-ft long steel bed which supports a variety of fixtures that are moved along the bed to suit assembly length variations. The fixtures have a motor-driven headstock, tailstock with live centers, rest blocks for supporting the parts during loading and roller steady rests that support the parts during welding. Air cylinders control the axial motion of both head and tailstocks.

Conventional submerged-arc welding equipment is mounted on ways on the new welding machine. A mechanical-type flux recovery unit and preheating units are also provided.

For additional information, write directly to the company at the above address.

Gas Cutting Machine

The Air Reduction Sales Co. has announced the availability of a new catalog on the 6B Oxygraph Gas Cutting Machine. This multiple torch machine and its accessories are fully described and illustrated in the 12-page, 2-color booklet.

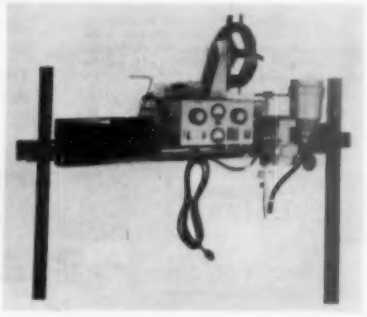
A copy may be obtained by writing Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y.

Welding Head Carriage

A new beam carriage for use with Hobart Models ASM-5D and ASM-5T automatic welding head is being announced by Hobart Brothers Co., Troy, Ohio.

The carriage is driven by a 110-v, d-c motor through a double-worm-gear reduction mounted in a gear case. A set of spur gears, mounted between the gear reducer output shaft and the carriage drive shaft, provides two travel speed ranges.

A friction roll, held securely against the back rail of the beam by a spring,



NEW! SIMPLIFIED! SMALLER!

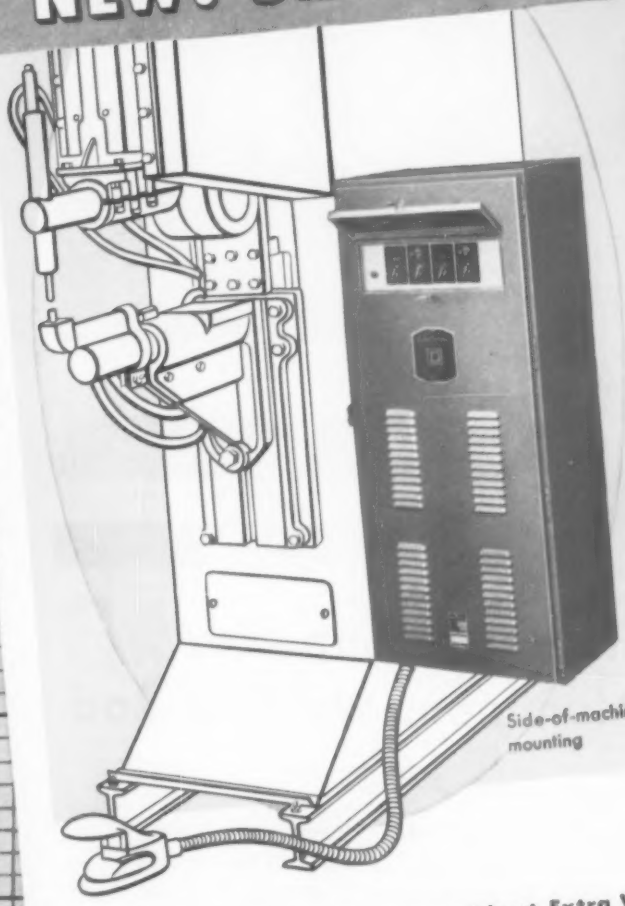
ELECTRONIC NON-SYNCHRONOUS WELDER CONTROL

Here is design simplification that affords significant advantages—easy installation, less maintenance, smaller size, mounting versatility.

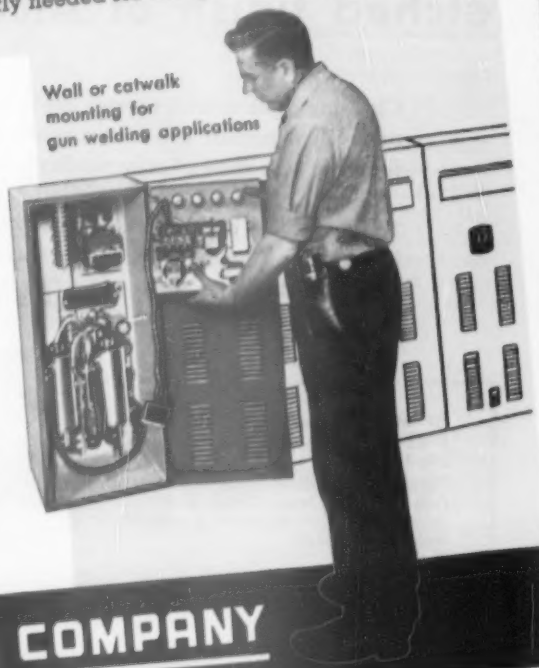
Drastically simplified NEMA 3B weld and sequence timing circuit requires only 4 tubes plus valve relay and firing relay. Extreme consistency and timing accuracy are maintained. All tube circuits are "fail-safe." Firing of power tubes is synchronized to minimize transients and ease stress on welding transformer.

Interchangeable NEMA 3B and 5B timer panels are quickly detached from door. Plug-connectors to power pack in cabinet permit easy replacement.

Much smaller in size, this new controller (15" x 15" x 37") requires little more space than formerly needed for the ignitron contactor alone.



Side-of-machine mounting



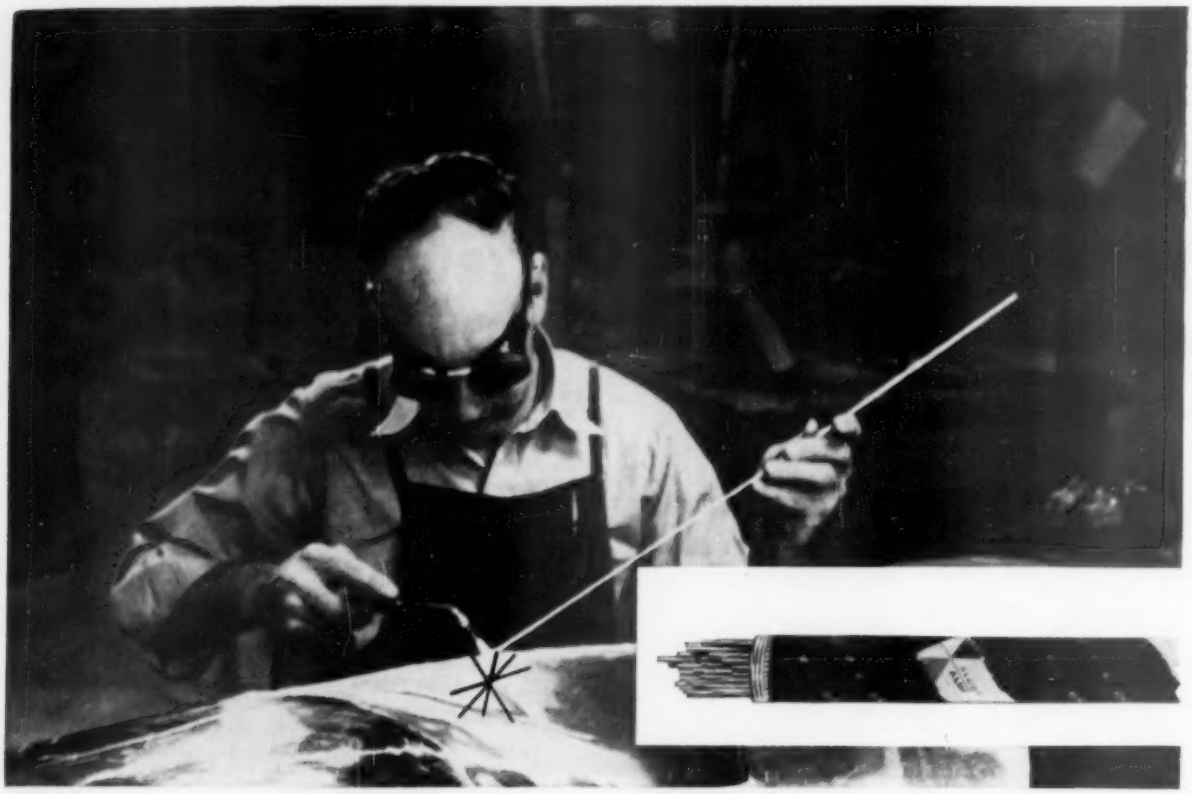
Wall or catwalk mounting for gun welding applications

Wall or Machine Mounting without Extra Work

• Enclosure design permits wall or side-of-machine mounting with the same controller and without the additional trouble of relocating adjuster dial assembly. Installation is made easier by generous wiring space below contactor, and vertical wiring channel extending the full height of the cabinet. All components are arranged for maximum accessibility.

Write for Bulletin 8992 on Electronic Non-Synchronous Welder Control and its application to spot and projection welders. Address Square D Company, 4041 N. Richards Street, Milwaukee 12, Wisconsin.

SQUARE D COMPANY



Here* is where you need the superior etched finish of Alcoa Aluminum Welding Rod

Cleaning alone cannot remove heavy oxides and other surface conditions customarily found on "as-drawn" wire surfaces.

Alcoa® Aluminum Welding Rod is *etched* to remove the entire outer layer of metal, leaving a surface that provides maximum rod "wetting" and freedom and control of weld flow.

This fine welding rod is now available in new, moistureproof, dustproof, resealable 5-lb tubes containing 36" straight lengths in all standard welding alloys and diameters. Buy it from the distributors listed at the right.

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FOR IMMEDIATE DELIVERY, call one of the Alcoa distributors listed below. He carries a complete range of alloys and sizes of Alcoa Etched Finished Welding and Brazing Rod, I. G. Consumable Electrode, Brazing Metal, Solder and Flux.

For technical assistance, contact the nearest Alcoa sales office, listed under "Aluminum" in the yellow pages of your phone book.

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Hinkle Supply Co.
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San Francisco
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COLORADO
Denver
M. L. Foss, Inc.
Marsh Steel Corp.
Metal Goods Corp.
CONNECTICUT
Milford
Edgcomb Steel of New England, Inc.
FLORIDA
Jacksonville
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Miami
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Pacific Metal Co.
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MARYLAND
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Whitehead Metal Products Co., Inc.
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Boston
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Detroit
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Steel Sales Co. of Michigan
MINNESOTA
Minneapolis
Steel Sales Co. of Minnesota
MISSOURI
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Marsh Steel Corp.
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NEW HAMPSHIRE
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Edgcomb Steel of New England, Inc.
NEW JERSEY
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Whitehead Metal Products Co., Inc.
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Miller Steel Co.
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NEW YORK
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Buffalo
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New York
(L. I. City) Adam Metal Supply Co., Inc.
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Straits Aluminum Company, Inc.
Whitehead Metal Products Co., Inc.
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Central Steel & Wire Co.
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Cleveland
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Jones & Laughlin Steel Corp.
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Columbus
Williams & Co., Inc.
Dayton
Ohio Metal & Manufacturing Co.
Toledo
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OKLAHOMA
Tulsa
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Portland
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Southern Oxygen Co.
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Milwaukee
Central Steel & Wire Company
Steel Sales Co. of Wisconsin

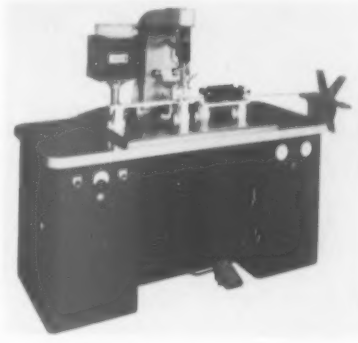
propels the carriage on 6 permanently lubricated, sealed rollers.

This beam carriage can be equipped to perform submerged-arc, inert-gas or open-arc welding. When equipped to do inert-gas welding, solenoid valves are supplied to control the flow of gas and cooling water.

For complete information write directly to Hobart Brothers Co., Hobart Square, Troy, Ohio.

Automatic Stud Welder

A newly developed, fully automatic stud welding machine is announced by Graham Manufacturing Corp., 31465 Stephenson Highway, Royal Oak 4, Mich.



Utilizing the Graham Process of Stored Energy Stud Welding this unit is fixtured for welding studs to strip stock fed continuously from a coil. Stud feed to the gun is automatic. Studs can be welded at the rate of approximately 80 per minute while power consumption averages $1^1/_2$ kva.

This unit can also be furnished with a revolving index table to permit stud welding of various individual parts or assemblies. A pedal is supplied to permit single stroke operation of the gun with automatic stud feed also possible.

Additional information may be had by writing directly to the Graham Manufacturing Corp., at the above address.

Stainless Brazing Alloy Paste

A new paste form of Nicrobraz stainless steel brazing alloy is now available from Stainless Processing Division, Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich. According to the manufacturer, this marks the first time that a stainless brazing alloy has been offered in easy-to-apply, easy-to-fuse paste form.

The new Nicrobraz Paste is recommended by Wall Colmonoy for use in all types of brazing applications involving stainless steels, nickel-base, cobalt-base and similar alloys as well as low-alloy steels, carbon steels, and copper. It produces a heat- and corrosion-resistant brazed joint and provides a thin corrosion-resistant overlay in the area surrounding the joint where protection is frequently required for low-alloy steels. It may be applied by brushing, dipping or any other type of hand or mechanical application when properly diluted for the method used.

For additional information write directly to Wall Colmonoy Corp. at the above address.

Spooled Wire and Electrodes

Ampco Metal, Inc., announces that Phos-Trode wire (AWS-ASTM E Cu Sn C) having an 8% nominal tin content is now available in 0.045, $^1/_{16}$, $^5/_{64}$ and $^3/_{32}$ in. diam sizes, layer wound on spools or rims for deposition with the gas metal-arc welding process.

Phos-Trode overlays are recommended by the manufacturer for many bearing and corrosion-resistant applications. In addition, it may be used for joining copper, tin bronzes, brasses, galvanized iron, cast iron and dissimilar metals.

Ampco Metal has also added $^5/_{64}$-in. diam Ampco-Trode 10 electrodes to their line. They are intended for braze Welding 16- and 18-gage mild steel with the metal-arc process and ACHF.

For further information, write–Ampco Metal, Inc., 1745 South 38 Street, Milwaukee 46, Wisconsin.

Hard-facing Additive

Development of an inexpensive welding additive by Western Carbide Corp., 6840 Vineland Ave., North Hollywood, Calif., has eliminated the need for many expensive specialized alloy rods now required for hard facing metals, according to the manufacturer. Reportedly, the use of this new additive has cut as much as 60% from the cost of hard facing.

The new additive is a scientifically compounded mixture of alloying elements and flux, called "W. C. Basic," and can be applied by any gas or arc

NO SINGLE

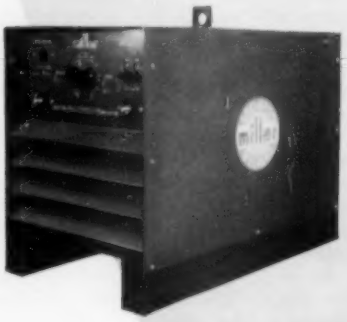
THERE'S EXACTLY THE RIGHT miller WELDER TO MEET EVERY WELDING REQUIREMENT

MILLER SR RECTIFIER TYPE DC ARC WELDERS

Available in 200, 300, 400 and 600 amperes, it is a superior direct current welder using Miller Unitran transformer control and selenium rectifiers for conversion from 3 phase AC line current. Miller SR Welders feature widest possible current range, extreme arc flexibility, maximum electrode deposition rate and highest electrical efficiency.

THE *New* MILLER SRH RECTIFIER TYPE DC ARC WELDER

A new concept in welder design for all DC metalic arc welding. Available in 200, 300 and 400 amperes. It is ruggedly constructed, compact, and is designed to lend itself to stacking for parallel operation or to conserve floor space. It has single range control and is weatherproof.



MILLER ARC WELDERS FOR TUNGSTEN ARC WELDING PROCESS

These Miller Welders feature the patented Miller UNITRAN control circuit which combines the transformer with its own integral flux diverter. This, in conjunction with adequate open circuit voltage, high frequency, balancing resistor and optional controls insures superior uniformity and flexibility throughout the entire welding range. Available in nine models.

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ELECTRIC MANUFACTURING CO., INC.
P.O. Box 798 Appleton, Wisconsin

"...if it's MILLER you know it's the finest..."

WELDER WILL DO IT ALL!

THE *New* MILLER MULTI ARC COMBINATION AC-DC WELDER

Available in 14 models, this new Miller Welder provides both AC and DC welding power for applications where both are required. It operates from a single phase power line and is available with high frequency and controls designed especially for inert gas arc and spot welding.

MILLER 100 SERIES HEAVY DUTY INDUSTRIAL TYPE AC WELDERS

Designed for heavy production welding and automatic welding applications. Available in eight models. The 100 Series Welders permit faster welding — as much as 35% faster. Movable coil design and 80 volts O.C.V. produces uniform and better welding characteristics throughout the entire range of the welder.

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- ☐ *Send me more information on the 100 Series Welders*

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welding technique. In gas applications, the Western Carbide additive may be applied by heating the rod and dipping it into W. C. Basic, thereby causing the alloying elements to adhere to the rod and enter the weld deposit.

For additional information, write directly to the manufacturer at the above address.

Portable Gamma-Ray Projector

A portable gamma-ray projector which is claimed to have decided advantages of economy and operation over conventional X-ray equipment used in industrial radiography is the subject of a new 24-page booklet.

As described in the booklet, the new projector offers a high degree of penetration yet is safe to operate, costs only a fraction as much as comparable X-ray equipment, is portable, and needs no electricity, control board or maintenance beyond replenishment or the radioisotope.

Of special interest in the booklet is a gamma-ray intensity and film exposure guide which permits a radiographer to locate and schedule work so as to minimize the disruption of other work and predict any unsafe working areas.

Copies of this booklet may be obtained from the Metal & Thermit Corp., 100 E. 42nd St., New York 17, N. Y., exclusive sales agent for the KEL-RAY projectors.

Ground Connection

The Magne-Cast Tool Co., Inc., 4900 W. Madison St., Chicago 44, Ill., announces the availability of their Welder Ground Hog. It has an aluminum body and powerful, long-lasting built-in Alnico magnets. It can be used on flat, round or angular surfaces.

For additional information write directly to the company at the above address.

New Guard Protects Pockets!
Meco
TRIPL-FLINT* SAFETY LIGHTER!
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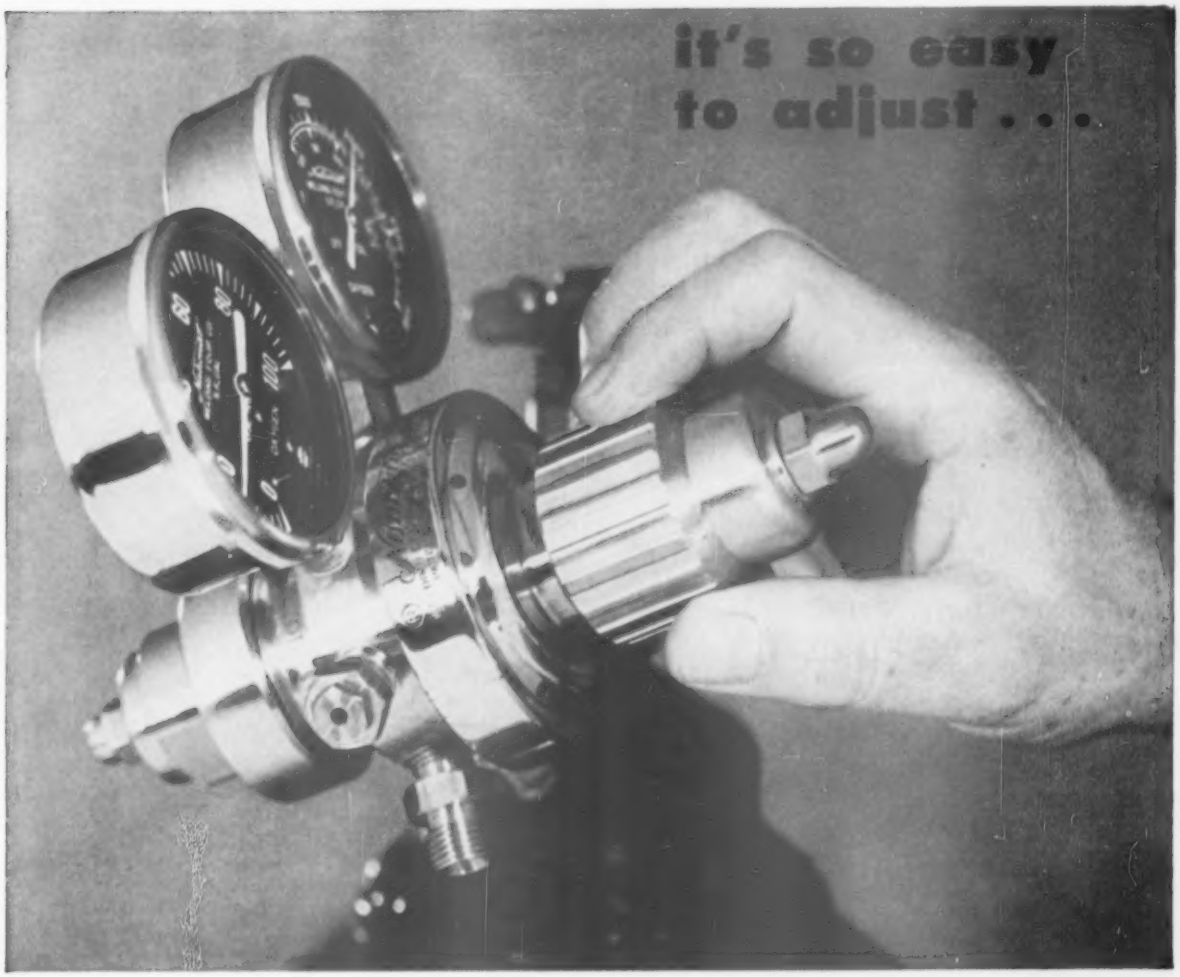

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The first time you touch the adjusting screw of this regulator you will be utterly amazed at its easy action.

Such adjustability and working accuracy suggests the wonderful care taken in the designing and manufacturing of this precision instrument — and one glance at the beautiful appearance shows quality throughout.

National of California

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Current Welding Literature

AGRICULTURAL MACHINERY. Induction Machine Pressure Welds Shafts Without Flash, D. L. Hansen. Iron Age, vol. 176, no. 11 (Sept. 15, 1955), pp. 144–145.

AIRCRAFT MANUFACTURE. Structural Spotwelding, W. R. Cain. Aircraft Production, vol. 17, no. 6 (June 1955), pp. 242–247.

ARC WELDING. Arc Welding for Small-Lot Production, A. Allen. Tool Engr., vol. 34, no. 6 (June 1955), pp. 92–96; vol. 35, no. 1 (July), pp. 83–87; no. 2 (Aug.), pp. 89–93.

ARC WELDING. Economics of Automatic Arc Welding, E. W. McKeown. Commonwealth Engr., vol. 42, no. 9 (Apr. 1955), pp. 341–346.

AUTOMOBILE MANUFACTURE. Multiple Spot Welding by "Press Welding" Technique. Machy. (Lond.), vol. 87, no. 2229 (Aug. 5, 1955), pp. 284–293.

BICYCLES. Cycle Rim Manufacture. Engineer, vol. 199, no. 5182 (May 20, 1955), pp. 712–714.

BRAZING. How to Braze Varying Gages. Steel, vol. 137, no. 11 (Sept. 12, 1955), pp. 115–116.

BRIDGES, STEEL. Welded Bridge Speeds Oil Cargo Handling from Flating Dock, W. E. Blessey. Civ. Eng. (N. Y.), vol. 25, no. 8 (Aug. 1955), pp. 40–44.

ELECTRIC ARCS. Characteristics of High-Current Argon Arcs with Various Electrode Materials, J. W. Dzimianski and T. B. Jones. Am. Inst. Elec. Engrs.—Trans. vol. 74, pt. 1 (Communications & Electronics), no. 16 (Jan. 1955) pp. 665–669; (discussion), 669–670.

ELECTRIC CABLES. Repair of Thermoplastic Cable Jackets Using Hot Gas Welding, R. A. Pringle and A. D. Varenelli. Wire & Wire Products, vol. 30, no. 6 (June 1955), pp. 678–680, 712–713.

ENGINE MANUFACTURE. Fabrication of Welded Steel Crankcase for Light-Weight Two-Cycle Diesel Engine, A. C. Drechsler. Gen. Motors Eng. J., vol. 2, no. 2 (Mar.–Apr. 1955), pp. 8–15.

JIGS AND FIXTURES. How to Design and Build Welded Valve Panels, H. W. Brown and J. H. Smith. Applied Hydraulics, vol. 8, no. 5 (May 1955), pp. 65–67, 114.

LIBRARIES. Building Straddles Highway Over River. Eng. News-Rec., vol. 155, no. 8 (Aug. 25, 1955), pp. 34–36.

METALS AND ALLOYS. Review of High Temperature Metal-Ceramic Seals, H. Palmour, III. Electrochem Soc.—J., vol. 102, no. 7 (July 1955), pp. 160C–164C.

PIPE LINES. Radiographic Inspection of Petroleum Pipe Lines, H. Hovland. Am. Petroleum Inst.—Proc., vol. 34, Sec. 5 (1954), pp. 35–39.

PRESSURE VESSELS. Stress-Relieving Large Welded Pressure Vessel by Gas. Heating & Air Treatment Engr., vol. 18, no. 6 (June 1955), pp. 149–151.

RESEARCH. British Welding Research Association. Metallurgia, vol. 52, no. 310 (Aug. 1955), pp. 57–61; see also Sheet Metal Industries, vol. 32, no. 340 (Aug. 1955), pp. 606–607.

RESISTANCE WELDING. Resistance Welding of Stabilized Stainless Steel Strip, E. J. Keefe and D. R. Nash. Welding & Metal Fabrication, vol. 23, no. 8 (Aug. 1955), pp. 289–294.

SHIPBUILDING. S. S. *Ocean Vulcan* and S.S. *Clan Alpine*. H. E. Jaeger. Shipbldg. & Shipg. Rec., vol. 86, no. 10 (Sept. 8, 1955), pp. 307–308.

SHIPBUILDING MATERIALS. Present Position of Aluminum in Shipbuilding, E. G. West. Welding & Metal Fabrication, vol. 23, no. 6 (June 1955), pp. 194–203; no. 8 (Aug.), pp. 299–306.

SOLDERING. Eight Techniques to Improve Solder Assemblies, G. Olsen. Am. Mach., vol. 99, no. 16 (Aug. 1, 1955), pp. 89–94.

SOLDERING. Solderability: Many Factors Affect Joint Quality, H. Schwartzbart. Iron Age, vol. 176, no. 12 (Sept. 22, 1955), pp. 110–113.

TANKS, OILS. Study of Brittle Failure in Tank Steels, F. J. Feely, Jr., M. S. Northup. Am. Petroleum Inst.—Proc., vol. 34, Sec. 3 (1954), pp. 168–179; (discussion), 179–185.

TANKS. Road Tanker Production. Welding & Metal Fabrication, vol. 23, no. 8 (Aug. 1955), pp. 286–288.

TITANIUM. Fusion Welding Unalloyed Titanium Sheet, A. V. Levy and R. Wickham. Aircraft Eng., vol. 27, no. 317 (July 1955), pp. 216–219.

TUBES. New Control System Cuts Scrap Loss on Tube Welding Line, D. C. Fisher. Iron Age, vol. 176, no. 5 (Aug. 4, 1955), pp. 84–86.

WASHING MACHINES. Resistance Welding Simplifies Presswork, J. H. Bauer. Iron Age, vol. 176, no. 10 (Sept. 8, 1955), pp. 80–81.

WELDING. Some Interesting Welding Investigations, W. P. Campbell and M. J. Nolan. Can. Metals, vol. 18, no. 8 (July 1955), pp. 42–45; no. 9, (Aug.), pp. 47–48, 50.

WELDING. There's Lots New in Welding, P. Stern. Soc. Automotive Engrs.—J., vol. 63, no. 1 (Jan. 1955), pp. 46–48.

WELDING. Process and Tool for Better, Faster Production Welds, R. Cleveland. Welding Engr., vol. 40, no. 7 (July 1955), pp. 22–24.

X-RAY ANALYSIS. Radiographic Standards for Quality Control of Aluminum Alloy Butt Welds by Self-Adjusting Arc Process, J. G. Young. Welding & Metal Fabrication, vol. 23, no. 8 (Aug. 1955), pp. 278–285.

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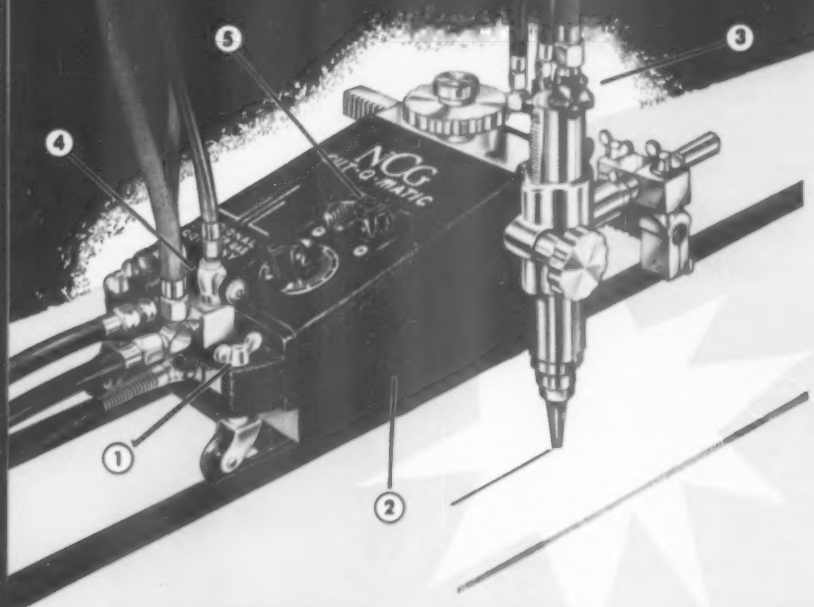

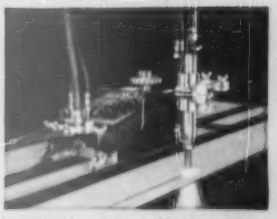

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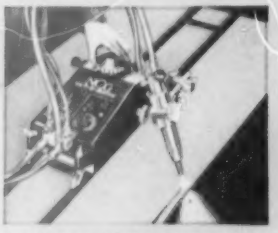
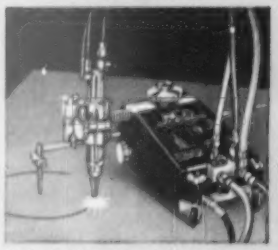
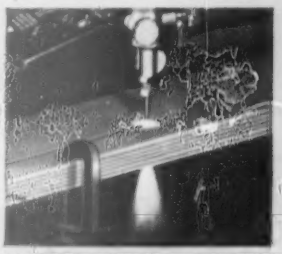


Bevel Cutting—Straight or circle cuts can be made to any bevel angle by a simple adjustment of the **Cut-O-Matic** torch holder



Circle Cutting—True circles and arcs, 3 inches to 60 inches in diameter with either square or bevel edges, are cut easily by attaching the radius rod assembly furnished with each machine.



Stack Cutting—Where many pieces of the same dimensions are needed, stack-cutting with the **Cut-O-Matic No. 7** provides real production line economies. Simply clamp plates as shown and use larger size cutting tip.

1 New torch stabilizing device brings new cutting accuracy—A new, unique *floating rear caster* assembly practically eliminates machine wobble and side tilt, when passing over rough, unevenly surfaced plate. Gives production-line accuracy, clean, smooth edges, no finishing.

2 New design cuts 20 lbs. off weight—Almost unbelievably, this new improved CUT-O-MATIC now weighs less than 30 lbs., for ready portability, greater ease of handling—yet it's more rugged than you'll ever need.

3 New 3-hose torch now spells improved cutting efficiency—The new CUT-O-MATIC 3-hose torch has individual oxygen hose to both preheat and cutting orifice, simplifying preheat oxygen adjustment and assuring more efficient cuts.

4 New simplified Gas control—A new valve block assembly now locates preheat controls on machine, separated from high pressure oxygen control on the torch. Adjustments on preheat now made freely without disturbance to oxygen control.

5 New switch is maintenance-free for life of machine—New rotary-type switch, exclusive with NCG, provides trouble-free starting, stopping and reversing for life of machine. Has silver electrical contacts, is permanently sealed against grit and dirt.

CUT-O-MATIC has been redesigned throughout, offers many more advantages than those mentioned here. No other portable flame-cutting machine like CUT-O-MATIC. Get proof, the full story. Ask for a demonstration or write for new big broadside from any authorized NCG dealer or nearest NCG office or address below.

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PERSONNEL

Past-President Hill Honored by API

At the recent annual meeting of the American Petroleum Institute in San Francisco, the General Committee of the Division of Production conferred its highest honor upon Harold O. Hill, a past president of the AMERICAN WELDING SOCIETY. On Tuesday afternoon, No-

Harold O. Hill

vember 15th, Mr. Hill was presented with the API "Certificate of Appreciation," as a well deserved recognition of his long outstanding service to the Institute, particularly his leadership and constructive participation in tank standardization. The presentation was made by A. W. Thompson, vice-president for production.

Mr. Hill is assistant-chief engineer of the Fabrication Division, Bethlehem Steel Co., Bethlehem, Pa.

THE AWS IS FOR YOU!

If you weld or if welding is in any part of your fabrication program, you cannot afford not to be an AWS member. Write to American Welding Society, 33 West 39th Street, New York 18, N. Y. for details.

Van Scoy Appointed Sales Engineer

C. R. Van Scoy has been appointed Sales Engineer for Southern California by Superweld Corp., North Hollywood, Calif. His, professional experience includes more than 12 years in sales and engineering work. Prior to joining Superweld, Mr. Van Scoy was owner and operator of Lafayette Metal Products, Inc.

Brown Made Manager

Charles Brown has been appointed Manager of the Southern Division office of All-State Welding Alloys Co., Inc., which has been established at 3 Pamona Drive, Birmingham 9, Ala. He will have supervision of All-State regional offices at New Orleans, St. Louis, and Concord, Tenn., in addition to the one at Birmingham. Announcement to this effect was made by T. D. Nast, president, at the company's offices, 249–55 Ferris Ave., White Plains, N. Y.

Charles Brown

After college and years of teaching and of serving as training director for such companies as Rust Engineering Construction Co. and Atlas Powder Co., Mr. Brown had long experience performing welding consulting services for the U. S. Army and Navy arsenals, AEC contractors, the U. S. Air Force and others. Utilization of specialty alloys has been his particular concern for some ten years.

Mr. Brown is a member of the AMERICAN WELDING SOCIETY—has addressed many of its meetings. He is also an occasional speaker for such other groups as the Instrument Society of America and the American Society of Tool Engineers.

Schwartzbart Promoted by Armour

Harry Schwartzbart has been promoted from research metallurgist to supervisor of welding research in the metals research department at Armour Research Foundation of Illinois Institute of Technology, Chicago.

Harry Schwartzbart

Schwartzbart, who joined the Foundation in 1951, has specialized in projects involving welding, brazing, soldering and mechanical metallurgy, and has published a number of papers in these areas.

Before joining the Foundation, he served three years as a research metallurgist for the National Advisory Committee for Aeronautics, Cleveland.

Mr. Schwartzbart received his bachelor's degree from Pennsylvania State University in 1943 and his master's in 1948.

Mr. Schwartzbart, who was in the Navy during 1944–46, is a member of the AMERICAN WELDING SOCIETY, the American Society for Metals, the American Institute of Mining and Metallurgical Engineers and the Institute of Metals.

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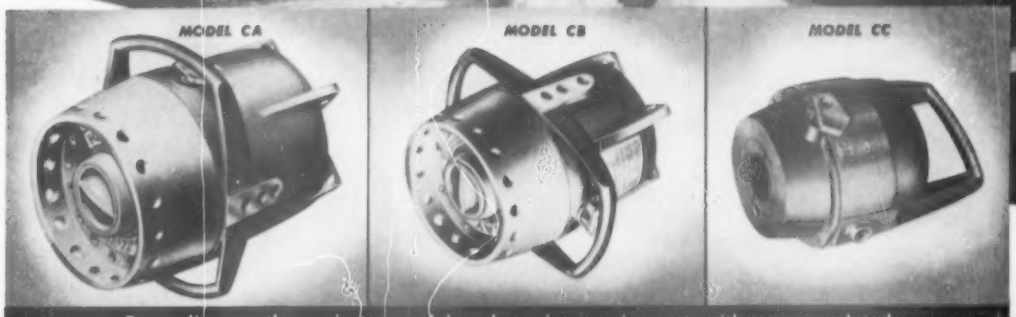
A safe versatile tool for Radiography with gamma rays.*



Depending on the projector model and service requirements either encapsulated Cobalt 60, Cesium 137 or Iridium 192 is used as the gamma ray source.

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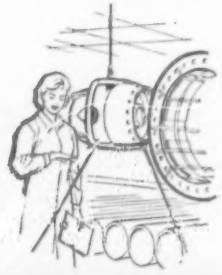
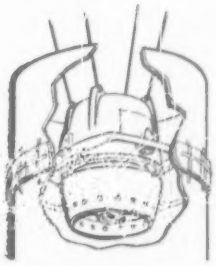


SAFE

KEL-RAY projectors have extremely low radiation leakage. . . so low they can be shipped and stored without additional shielding. They are tamper, fire, and shock proof. Operated under prescribed procedures, leakage is below the AEC limit.



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A single set-up can produce either spot, doughnut, or hemisphere panoramic radiographs. Thick steel sections can be radiographed; sensitivity is so great even incandescent lamp filaments have been radiographed with a KEL-RAY projector.

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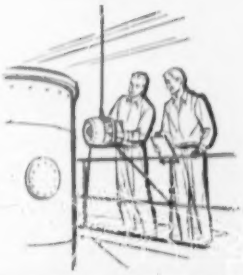
Designed for field or shop use, the smallest model can be carried by hand—largest is transported and positioned speedily with standard equipment for materials handling and rigging.



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Each of the three KEL-RAY Projector models is a portable, powerful, shielded, self-contained source of penetrating radiation for non-destructive inspection in maintenance, construction or quality control. There is a KEL-RAY Gamma Ray Projector that can improve your operations —save you time and money! Write for detailed literature.

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ABSTRACTS OF CURRENT PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of patents, Washington 25, D. C.

2,718,690—Method of Producing Composite Metals—John B. Ulam, Bethel Township, Allegheny County, Pa.

This patent relates to a method of making a composite body from a plurality of metal sheet components, such as a sheet of copper and a sheet of stainless steel. The process comprises mechanically removing the attaching surfaces of each of the metal components and stacking the components with the newly exposed molecular surfaces of the different metals in contact with each other. The cleaned surfaces of the stacked components are sealed from the atmosphere and the assembly is heated to a predetermined temperature to dilate the molecular structure of the composite parts. The heated assembly is subjected to a working pressure to diffuse the cleaned contacting surfaces together and to form an integral body therefrom.

2,718,864—Welding Alignment Apparatus—John Price Fike, Milwaukee, Wis., assignor to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

Fike's patent relates to an apparatus for aligning the adjacent ends of two pipe sections to be welded together. The apparatus includes an internal aligning clamp disposed within the pipe sections and aligned with the joint between the adjacent ends thereof, which clamp can be expanded into contact with the pipe sections to align and secure them in proper welding position. Cable means extend in opposite axial direction from the clamp and connect to end braces that engage the outer ends of the two pipe sections so that the cable can be tightened to force the two pipe sections together tightly.

2,719,207—Apparatus and Method for Producing a Nonoxidizing Atmosphere for Flash Welding—Harris P. Moyer, Menomonee Falls, Wis., assignor to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

A shield for use with a welding apparatus is provided by this patent wherein the apparatus positions the ends of two metal sections to be welded together in opposed aligned relationship by a pair of clamping members, which clamping members can be moved relative to each other to bring the metal section ends into contacting relation. Compressible material is provided between the clamping members that have a longitudinal opening therein in which opening the ends of the members to be welded are positioned. Other means are provided for purging the opening with nonoxidizing gases prior to and during welding to remove oxidizing agents therefrom through the porous material and prevent the formation of oxide inclusions in the weld.

2,719,208—Wrapped Alloy Core Electrode—Richard K. Pitler, Menands, N. Y., assignor to Allegheny Ludlum Steel Corp., Brackenridge, Pa., a corporation of Pennsylvania.

The patented electrode comprises a longitudinally extending, aluminum-sheathed core of alloying material, and enclosing end, side, top and bottom wall portions of highly compacted and bonded base metal material of the class of titanium and zirconium is provided around the core of alloying material.

2,719,209—Arc-Welding Apparatus—Martin Rebuffoni, Williamsville, N. Y., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This patent relates to control circuit means for arc-welding apparatus for welding with a nonconsumable electrode of the tungsten type. The patent covers the association of various relays, contact means and control solenoids in the control circuit for the desired welding action.

2,719,210—Method of Welding Thin-Walled Tubes From a Single Side—Edward C. Chapman, Chattanooga, Tenn., assignor to Combustion Engineering, Inc., New York, N. Y., a corporation of Delaware.

Chapman's patent is on a method of welding together two parallel, spaced, thin-walled tubes of ferrous metal continuously along their adjacent longitudinal portions. Initially the space between the tubes is substantially completely spanned with ferrous metal backed up by a backing strip extending longitudinally of the space and in spanning relation with the space. This backing strip is capable of being in direct contact with the ferrous metal for a limited period of time when the ferrous metal is in a molten state without such backing strip itself becoming fused. In the method, a localized welding heat is applied directly to the ferrous metal between the tubes, the localized welding heat is moved longitudinally of the tubes along the ferrous metal at a rate so that the portion of the ferrous metal in the vicinity of the heat is completely fused and is united with the tubes, but remains substantially independent of the backing strip which thereafter is removed.

2,719,245—Wire Feeding System For Welding Apparatus—Nelson E. Anderson, Berkeley Heights, N. J., assignor to Air Reduction Co., Inc., New York, N. Y., a corporation of New York.

In this wire feeding system, a welding head is provided remote from a source of electrode wire and electric motor-driven means are provided for propelling the wire longitudinally to the welding head. Governor means are provided remote from the motor-driven means and are capable of being actuated solely by the longitudinal motion of the wire and be responsive to changes in speed of the wire. Other electrically conducting means operatively interconnect the governor means with the motor-driven means.

2,719,800—Flux Composition and Its Method of Production—Charles P. Veltri, Miami, Fla.

This flux composition is for use in brazing, welding or similar operations and it is made by mixing parts of pulverized borax with pulverized bicarbonate of soda and boric acid. Thereafter pulverized sodium chloride and ammonium chloride are added and a mild reaction takes place by which the ammonium chloride becomes coated. Thereafter parts of air-slaked lime are added and the mixture is permitted to age until it becomes a hardened mass. Lastly, the mass is pulverized and is available for use.

2,719,801—Arc-Welding Compositions—Leonidas Keever Stringham, Shaker Heights, and Paul E. Jerabek, Euclid, Ohio, assignors to the Lincoln Electric Co., Cleveland, Ohio, a corporation of Ohio.

The patented flux composition is particularly adapted for use in arc welding and a flux is maintained in granular free-flowing particles by means of anhydrous sodium silicate present in the flux. The flux also includes fixed percentages of manganese ore, alumina, magnesia, silica, fluorspar and a killing agent such as silico-manganese.

2,719,899—Automatic Dual Electrode Control for Arc-Welding Machines—Harry F. Schwarting, Webster Groves, Mo., assignor to American Car and Foundry Co., New York, N. Y., a corporation of New Jersey.

A pair of spaced resilient electrode guiding members adapted to be positioned cross-wise above the welding gap between two adjacent edges of metallic members

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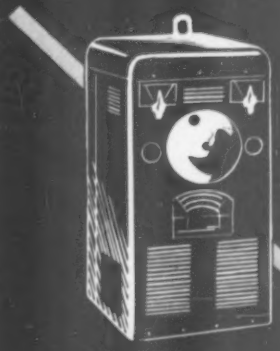

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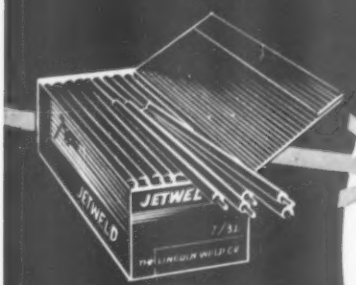

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to be seam-welded together are shown in this patent. Other means are engagable with the edges of the metallic members and are shiftable during the welding operation in response to variations in the width of the gap due to irregularities of the edges of such members. These shiftable means are operatively connected with and act to increase the distance between the electrode guiding members in accordance with the increase in the width of the welding gap.

2,719,900—High-Speed Sheet Metal Inert-Gas Shielded-Arc Welding—John A. Persson, Kenmore, N. Y., assignor to Union Carbide and Carbon Corp., a corporation of New York.

This arc-welding process is adapted to be used for seam-welding sheet metal at a speed of at least 1000 ipm. In the process, one edge of each of the stock metal sheets to be welded has a flange provided thereon to make an included angle of less than 90 deg with the remainder of the sheet. Such flanged edges are abutted, and the flange and adjacent metal along the seam are progressively melted with a metal fusing electric arc. This arc is shielded with a suitable gas and the arc is moved at a speed in excess of 1000 ipm relative to the seam.

2,719,902—Multi-Element Electrode—James H. Flynn, Birmingham, Mich., assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

Flynn's patent relates to an electrode for use in electrical cutting operations. The electrode comprises a plurality of generally annular, spirally disposed electroconductive segments in electrically nonconductive relationship with respect to one another.

2,719,946—Multiple Phase Transformer and Dry Disk Rectifier Assembly for Resistance Welding Machines and the Like—Joseph J. Riley, Warren, Ohio, assignor to the Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

This patent relates to direct-current power supply means for resistance welding action and the like. The power supply comprises a three-phase transformer bank made from three single-phase transformers, each of which has a U-shaped secondary loop. Other special features of construction are covered in the patent.

2,720,022—Method of Making Tubing from Strip Metal Stock—Andrew J. Snively, Huntington Woods, Mich., assignor to Bundy Tubing Co., Detroit, Mich., a corporation of Michigan.

Snively's patent relates to a method of making tubing with a double thickness wall from a single strip of metal stock. In making the tubing, a ribbon of bonding metal having a melting temperature lower than that of the strip is provided in the rolled tubing assembly, and thereafter the assembly is heated to melt such bonding metal and deposit it in the rolled tubing to hold such assembly in desired tubular, wrapped shape. The resultant tubing is supposed to have substantially the same critical strength and working properties of the double thickness wall at all portions of the tube.

2,720,473—Potassium-Supplying Welding Flux Ingredient—John W. Donahey, Paoli, Pa., assignor to Foote Mineral Co., Philadelphia, Pa., a corporation of Pennsylvania.

This patented flux is a water-insoluble, hydrophobic composition in the form of a glass frit. The frit is made essentially from parts of potassium oxide, titanium dioxide and silicon dioxide. Other oxides in specified quantities go into the frit to complete the composition of this flux ingredient.

2,720,574—Bonding Members Having Irregularities—John M. Felton, Wellsburg, W. Va., assignor to Wheeling Steel Corp., Wheeling, W. Va., a corporation of Delaware.

This method of bonding sheet metal edges together includes the steps of disposing the edges of a pair of sheet metal sections in juxtaposition and where one edge is a sheared edge having a shear fin projecting outwardly beyond the plane of a face of the sheet. A presser is provided to engage the edges of the faces of the sheets disposed away from a flat supporting surface and such edges are pressed toward the surface throughout the full extent of the edges. This reduces the shear fins and bonds together the edges of the metal sections.

2,720,575—Method of Brazing a Joint—Frederick M. Potter, Washington Township, Bergen County, N. J., assignor to Bendix Aviation Corp., Teterboro, N. J., a corporation of Delaware.

Potter's patent is on a method of welding or brazing the ends of two rectangular conductors together. The method includes the steps of shaping the ends of the conductors to form a horizontal S-shaped configuration and interlocking the S-shaped sections with a strip of brazing material placed therebetween. Next a high electrical current is passed through the surfaces of the S-shaped section while maintaining pressure uniformly over the interlocking sections to urge the sections together.

2,720,855—Ferrule Heating Unit for a Lead Wire Ferrule Brazing Machine—George D. Brent, Bloomfield, N. J., and Ernest K. Bee, Fairmont, W. Va., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This patent relates to a brazing machine for brazing a plurality of lead in conductors to respective ferrules of sealed beam lamp reflector assemblies. The patent is on the specialized mechanical features of the machine.

2,721,248—Tube Welder—Floyd M. Kirkpatrick, Erie, Pa., assignor to General Electric Co., a corporation of New York.

This tube welder includes a rotatable annular member and means for holding the tubing concentric with the annular member. An electrode is provided on the interior of the annular member, and means are present for supplying current to the electrode for effecting an arc between the electrode and the tubing to be welded. Other means rotate the annular member whereby rotation is provided between the electrode and the tubing to effect a circumferential weld on the tubing.

2,721,249—High-Speed Arc Welding—George G. Landis and Emmett A. Smith, Cleveland, Ohio, assignors to the Lincoln Electric Co., Cleveland, Ohio, a corporation of Ohio.

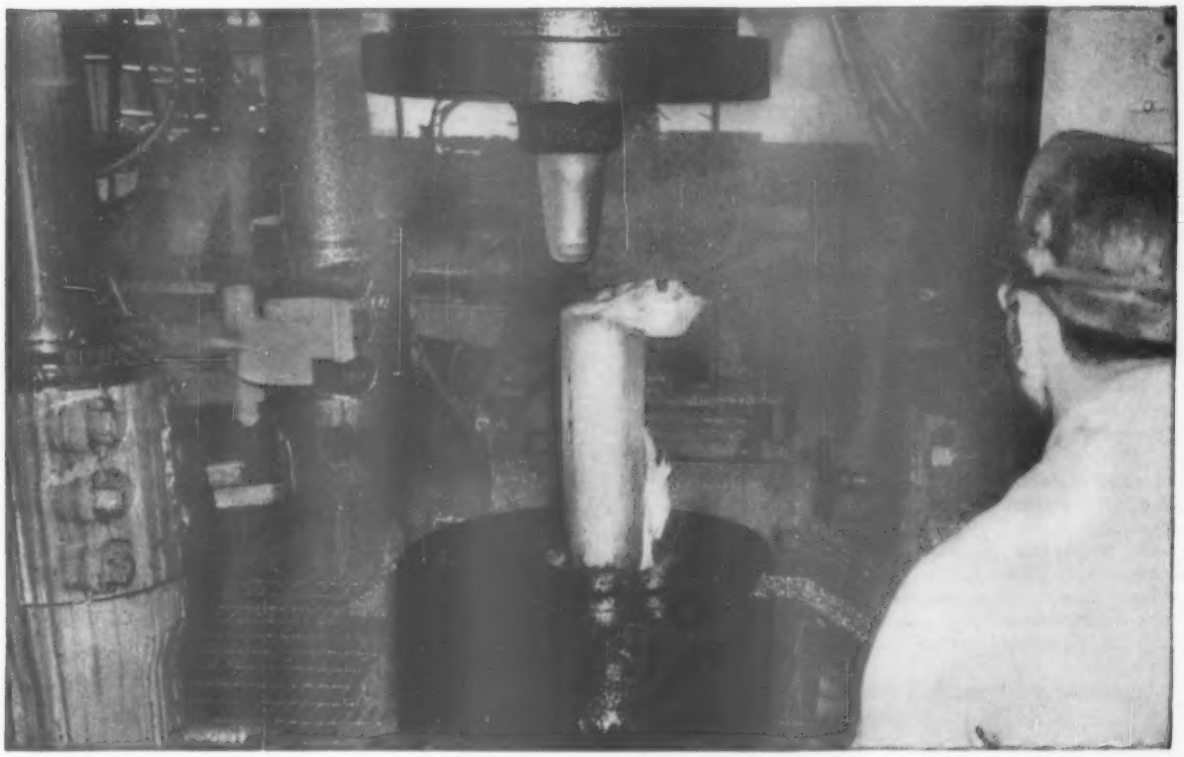
This patent relates to a method of arc welding wherein an arc is established between a metal workpiece and the end of a metal electrode. The method includes the steps of striking an arc between the end of the electrode and the workpiece and continuously feeding the electrode to the workpiece while continuously passing through the terminal portion of the electrode an arc-welding current of high density. The length of the terminal portion traversed by the current in relation to the rate of feed of the electrode is such that the current serves to raise the electrode to a temperature near its melting point.

2,721,250—Inert-Gas Welding Torch Nozzle—Milton N. Franklin, Philadelphia, Pa.

A new type of a torch tip is provided by this inventor, and it includes a hollow, cone-shaped ceramic torch cup to be attached at one end to a torch. A metallic thin-walled tubular extension protrudes beyond the free end of the torch cup and has an outer cone-shaped wall portion received in and shaped complementary to the inner wall of the torch cup. An insulating ring aids in securing the tubular extension member in the torch cup.

2,721,306—Synchronous Timing Control for Electric Resistance-Welding Apparatus—Joseph J. Riley and Lauri J. Murto, Warren, Ohio, assignors to the Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

A circuit apparatus for timing the duration of the flow of welding current in electric resistance-welding apparatus is covered by this particular patent. The apparatus includes a source of alternating current energy, an initiating valve having an anode, cathode and grid electrode, means to connect the anode and cathode to the current source while other means comprising the current source and phase shifting means are provided to impress a control potential on the grid electrode. Other specialized valve and control means are provided in the timing control apparatus.



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For information on procedures for applying and for available sizes and prices, write for the booklet "HASTELLOY Alloy C—A Machinable Hard-Facing Alloy."

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NEW LITERATURE

Metallizing of Flat Surfaces Covered by Standard Recently Released by AWS

Metallizing of flat surfaces is the subject of the fourth report in the series under the general title "Recommended Practices for Metallizing." This standard provides an authoritative source of information for metallizing flat surfaces of metal parts such as lathe or other machine tool ways, gibs, machine tool beds, improperly machined machine components, platens, etc., and noncylindrical surfaces in general for the purpose of restoring such parts to size or providing specific surface characteristics.

Equipment requirements, methods of surface preparation, metal spraying procedures, and finishing of sprayed metal parts are covered in detail. Handy tables provide data on the weights and types of wire used for spraying and the mechanical and physical properties, of sprayed metals. Also included are two formulas for computing the rate of spraying.

Copies of this new standard, "Recommended Practices for Metallizing: Part 1D—Metallizing Flat Surfaces," are available from the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y., at 50 cents each.

New AWS Recommended Practice Deals with Welding of Low Chromium-Molybdenum Steel Piping

A problem of much concern in the power, petroleum, chemical and other related fields is the subject of one of the latest "Recommended Practices," just issued by the AMERICAN WELDING SOCIETY. This publication deals with the interruption of heat cycles in the welding of low chromium-molybdenum steel piping materials. The recommendations apply to materials containing up to, and including, 5% chromium and 1% molybdenum.

Present practices in the various industries are given regarding the interruption of preheat and welding. The five factors to be considered in determination of the heating cycle are outlined in detail. Finally, recommendations based on industry experience are made for specific materials.

Copies of "Recommended Practices for Interruption of Heat Treatment Cycles for Low Chromium-Molybdenum Steel Piping Material" are available from the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y., at 50 cents each.

Lessons in Arc Welding

Lessons in Arc Welding. 200 pages. Price, $1.00. Published by Hobart Trade School, Inc., Hobart Square, Troy, Ohio.

A series of practical exercises and instructions for developing and improving the technique of arc welding operators. This book comprises the second part of the new and complete Hobart textbook *Modern Arc Welding* and contains the complete series of 40 arc welding exercises as used at the Hobart Trade School.

Although prepared as a textbook for operators, this volume contains information that would be of value to those designing parts for fabrication by arc welding.

Lessons covered include preliminary instruction, starting and manipulating the arc, welding common joints with bare electrodes, welding light-gage sheet with coated electrodes, general welding with coated electrodes in the flat, horizontal, vertical and overhead position, pipe welding, welding cast iron, and special practices and tests. It is written in an easy to understand manner with descriptive pictures, charts and diagrams.

Reference Radiographs for Welds

After some four years of zealous effort by hard-working industry members of ASTM Committee E-7 on Nondestructive Testing, reference radiographs covering types and degrees of discontinuities in steel welds have been approved for publication by the American Society for Testing Materials. The reference radiographs are reproduced from master radiographs taken of official sample weld plates which are the property of ASTM. There are 35 radiographs in the form of transparencies mounted in standard 5- by 8-in. Keysort cards. Details of plate thickness, radiographic method and welding procedures are given on each card. The transparencies, although reproduced to a density level of approximately 1.0, retain the original radiographic contrast.

The reference radiographs are intended to serve as a guide for interpretation. No attempt has been made to establish limits of acceptability for any discontinuity.

The complete file of 35 radiographic transparencies can be purchased for $50 per set from ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

Alloys and Fluxes

A new folder published by All-State Welding Alloys Co., Inc., 249-55 Ferris Ave., White Plains, N. Y., answers users' questions with regard to the increasing number of problem-solving alloys and fluxes the company offers for work on steel in maintenance, production and construction.

The new folder is designed to shorten time lost at the operator level in such ways as selecting quickly the right alloy and its companion flux for the job at hand.

The folder is titled "How to Use and Apply All-State Alloys and Fluxes for Welding, Brazing, Soldering, and Cutting Steel." Single copies or a sufficient number to supply individual

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Hardness Chart

A chart which shows the approximate relation between hardness by various testing systems and tensile strength of carbon and alloy steels has been issued recently by the Tubular Products Division of the Babcock & Wilcox Co. The hardness systems covered are Brinell, Monotron, Vickers, and Rockwell (B, C & E scales). Copies of the data card are available free on request to the company's general sales offices at Beaver Falls.

Resistance Welders

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., introduces Bulletin 333—*General Machine Catalog*—for electric resistance welding.

This 12-page bulletin is divided into four sections: Industrial Applications, Manufacture and Service, Principles of Operation and Types of Electric Resistance Welding Machines.

For complete information of the Sciaky line of resistance welding machines and philosophy of design and fabrication, write direct to Dept. L-5 at the Chicago address for your free copies of Bulletin 333.

Ampco Welding News

The third-quarter issue of the *Ampco Welding News* was recently released by Ampco Metal, Inc. The feature article in this issue describes the use of Phos-Trode electrodes and the metal-arc process in the sheathing of Stehling wringer and setting-out rolls with red brass to steel in leather processing equipment. Other articles of interest are also included.

Copies of this issue can be obtained by writing Ampco Metal, Inc., 1745 S. 38th St., Milwaukee, Wis.

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REVIEWS OF NEW BOOKS

Railway Engineering

Hütte Railway Engineering; Surveying. Volume V (B) of the 28th edition of the German Handbook *Hütte*, published by Wilhelm Ernst & Sohn, Berlin 1955. Price 56 marks, 588 pages. (Reviewed by Dr. G. E. Claussen.)

Hütte is the German engineer's handbook. Restricted to four volumes in previous editions, it has now grown to six, of which two are divided into two volumes each. The present volume is one of two bearing the title "Volume V."

Three-quarters of the volume deals with railway engineering. Some of the subjects that are discussed are: route location, track, stations, locomotives, car building and brakes. The treatment is exhaustive and there are numerous bibliographies.

From the welding standpoint the volume provides many details of welded construction in German passenger and freight cars, including frames and bolsters. Methods of design based on fatigue are described in detail. The stiffness of riveted and welded designs are compared. There are several tables giving design stresses for mild- and low-alloy steels in fatigue in the presence of mild, medium and severe notches. For low-alloy steel (yield strength = 48,500 psi/min) the permissible tension-compression fatigue stress varies from 30,500 to 9000 psi as the severity of the notch increases from mild to extreme. Welded steel fireboxes with welded tubes have replaced the old copper fireboxes with rolled-in tubes in steam locomotives. Diesel locomotives receive scant attention, because they are not widely used. Welded rail joints are common in street railways, but have not yet received wide acceptance on the railways in Germany.

●

Residual Welding Stresses

Method for Measuring Residual Stresses and Its Application to a Study of Residual Welding Stresses, by R. Gunnert. Price, 20 Swedish kronor. 135 pages. Published by Almqvist & Wiksell, Stockholm.

A method for measuring residual stresses is described, which is recommended by IIW as a standard method for measuring residual welding stresses. The method consists in gaging the distances between 8 gage marks located in a circle with a diameter of 9 mm at the spot where the stresses are to be determined. The measuring of the distances is carried out before and after the relief of the residual stresses between the gage marks. This relief is carried out by means of drilling a groove around the spot to a depth of 6–8 mm. The measurement of the distances is established by means of the tensometer described with a maximum error of about ± 0.0005 mm. From the changes in distances between the gage marks owing to the stress relief the residual stresses in the measuring surface can be calculated. The measurements include a maximum error of ± 2 kg/mm^2 (3000 psi).

A study has been undertaken in connection with the intensity, distribution, relief and effect of residual welding stresses by using the method described.

In unconstrained flat plates the longitudinal stresses in the weld and in the vicinity of it are of the magnitude of the metal's yield point but the transverse stresses are lower with the exception of stresses in the root of the weld. In constrained plates very high stresses exist in the welds.

Equations are deduced for the distribution of residual welding stresses.

Different ways of relieving the residual welding stresses are investigated. The relief by means of overloading is critically investigated. Peening of the weld reduces the transverse stresses but not the longitudinal ones. Relief by heat treatment of 350° C and less reduces the stresses to the same extent as the yield point is lowered.

The residual welding stresses do not reduce the static and probably not the fatigue strength of the welded object but in regard to buckling and brittle fracture the residual welding stresses are detrimental.

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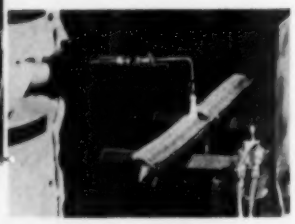

After spraying, the overlay is fused to the base metal.

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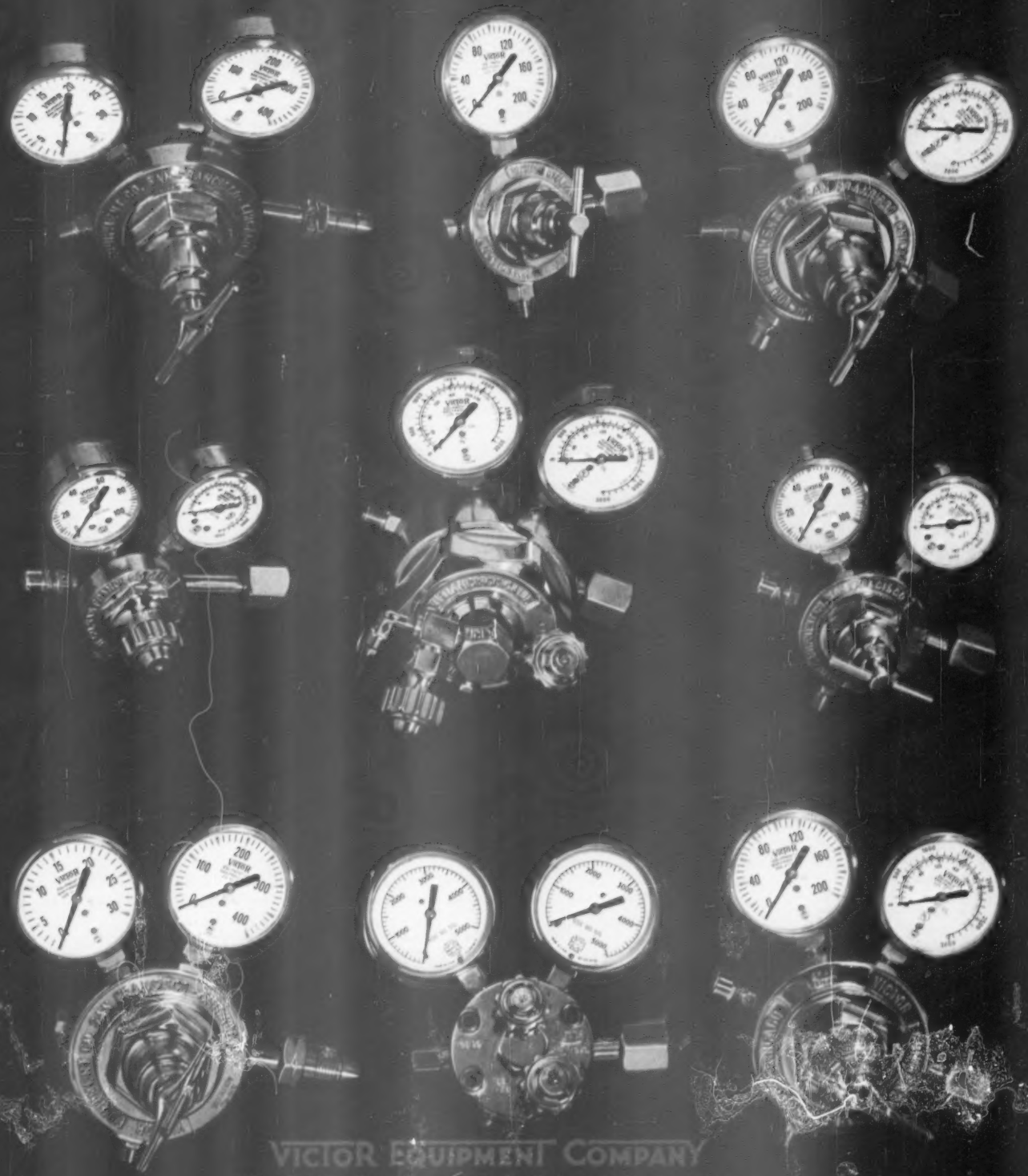

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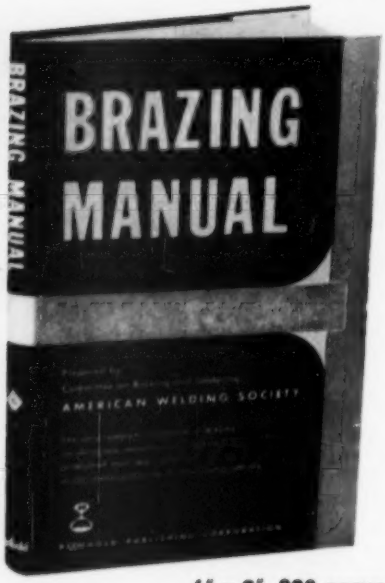

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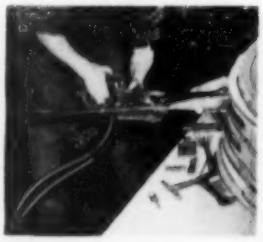

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SUPPLEMENT TO THE WELDING JOURNAL, DECEMBER, 1955

CRACK ARRESTING BY OVERLAYS OF NOTCH-TOUGH WELD METAL

Test program indicates that overlays of notch-tough welds can be used to protect welded structures by application at points where brittle fractures are known to initiate

BY P. P. PUZAK AND W. S. PELLINI

ABSTRACT. Crack-starter explosion tests were utilized to demonstrate the feasibility of using overlays of notch-tough welds to prevent the initiation and propagation of brittle fracture in otherwise brittle, structural mild steels. Simple bead-on-plate welds of notch-tough weld metal were deposited on the surfaces of a mild steel plate. Whereas fragmentation of the prime plate was obtained in crack-starter tests at 20 and 40° F, similar tests of plates featuring overlays of notch-tough weld metal demonstrated that brittle fractures do not propagate in overlay regions.

It is recommended that notch-tough weld deposits be considered for the protection of welded structures by application at points where brittle fractures are known to initiate, i.e., points of connections or discontinuities. The method is considered practical for application to existing or new structures.

Fig. 1 Fracture characteristics of mild steel plates illustrating relationship of surface shear to fracture propagation. Explosion crack-starter tests conducted at temperatures resulting in surface shear lips of thin, fin type (left), approximately 0.030 in. thickness (center) and approximately 0.080 in. thickness (right)

Introduction

Explosion-loaded, crack-starter tests of mild steel ship plate have demonstrated[1, 2] that the relative resistance of the steel to the propagation of brittle fracture is related to the development of surface shear (shear lip). At test temperatures such that the mild steel plates shatter completely, the unaided eye cannot discern evidences of surface shear (extremely tiny fins, however, are present). At higher temperatures, such that the plates resist fracture to the extent of limiting the cracks to the plastically deformed bulge regions, easily visible shear lips of 0.020 to 0.050 in. thickness are developed. The amount of shear lip increases rapidly at still higher temperatures to the point of developing complete shear across the section and completely ductile behavior is exhibited by the steel. Figure 1 illustrates the fracture characteristics of mild steel plates at temperatures such that the surface shear lip thickness is, respectively, nil, approximately 0.030 in. and approximately 0.080 in. It is evident that the surface-shearing process controls the relative fracture resistance of the steel. The appearance of shear lips in cross section is illustrated in Fig. 2.

The development of surface shear in lip form results from the fact that free surfaces approach a condition of stress biaxiality compared to the stress triaxiality which may be developed in the inner regions of thick plates. Thus, if the steel is tested over a range of temperatures involving a transition from complete brittleness (fracture surface entirely cleavage) to complete ductility (fracture surface entirely shear), the first portion of the fracture face to show ductile behavior is naturally the free surface region of lowest stress triaxiality. The important point is that a relatively minor thickness of surface shear lip imparts a large measure of resistance to the propagation of high velocity, brittle fractures. For a complete discussion of shear lips, the reader is referred to previous papers on the subject. [1, 2]

P. P. Puzak and W. S. Pellini are associated with Metal Processing Branch, Metallurgy Division, Naval Research Laboratory, Washington, D. C.

Presented at 1955 AWS National Fall Meeting, October 17–21, Philadelphia, Pa.

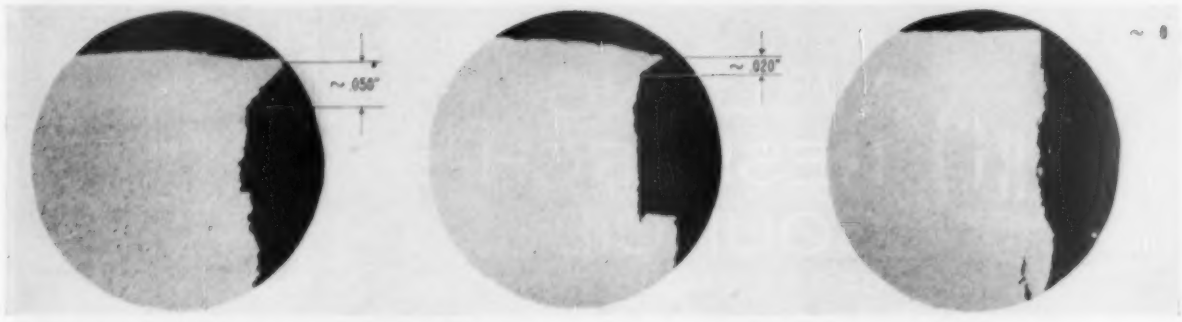

Fig. 2 Examples of shear lips on fracture surfaces

The findings that the propagation of brittle fracture was controlled by the energy absorption concomitant to the development of small amounts of surface shearing suggested cladding of mild steel plates with notch-ductile material for the purpose of providing an artificial region of surface shear. Overlays of highly notch-ductile weld metals were considered as a practical method of cladding. Previous studies of the notch-ductility characteristics of weld metals[3] suggested the use of ferritic E12015 and austenitic 25–20 type electrodes for this purpose. This paper presents results of preliminary studies demonstrating the feasibility of utilizing notch-tough, weld overlays to afford added protection against the initiation and propagation of brittle fracture in mild steel structures.

Materials

A mild steel plate of 1 in. thickness (Grade M, Mil Spec 4681j) was used as the base material for all tests to be described. Figure 3 illustrates the fracture characteristics of this material in explosion crack-starter tests. Figure 4 presents a comparison of the Charpy V transition curves of the mild steel plate and of the two weld metals used in the overlay studies. The weld metal Charpy specimens were machined from VV butt welds, as indicated in Fig. 4, and the plate specimens were machined in the conventional manner (longitudinal axis of specimen parallel to primary rolling direction of plate, and notched through the thickness). From known correlations with Charpy V tests, the mild steel would be expected to be highly brittle at temperatures of 20 to 40° F (see Fig. 3) but the weld metals would be expected to be ductile at these temperatures. Tests of weld-overlay plates were conducted at 20 to 40° F inasmuch as this temperature range was considered to be of interest as it represents the temperature range of the most severe casualties to the wartime ships using steels of similar crack-starter test fracture characteristics[4] and Charpy V transition features.[5]

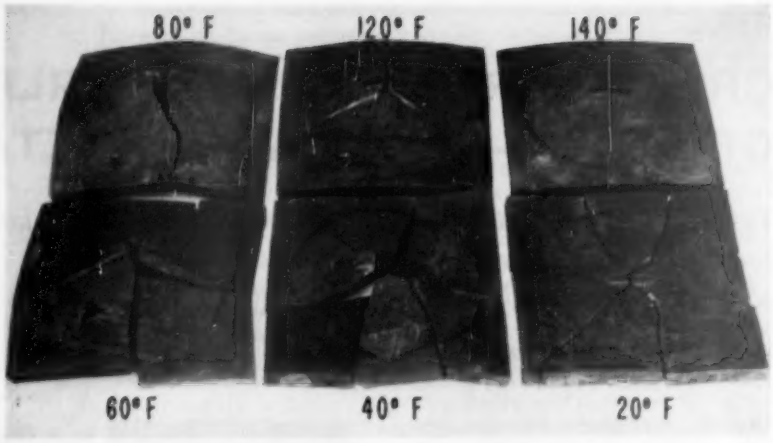

Fig. 3 Explosion crack-starter tests of mild steel plate material used in this investigation

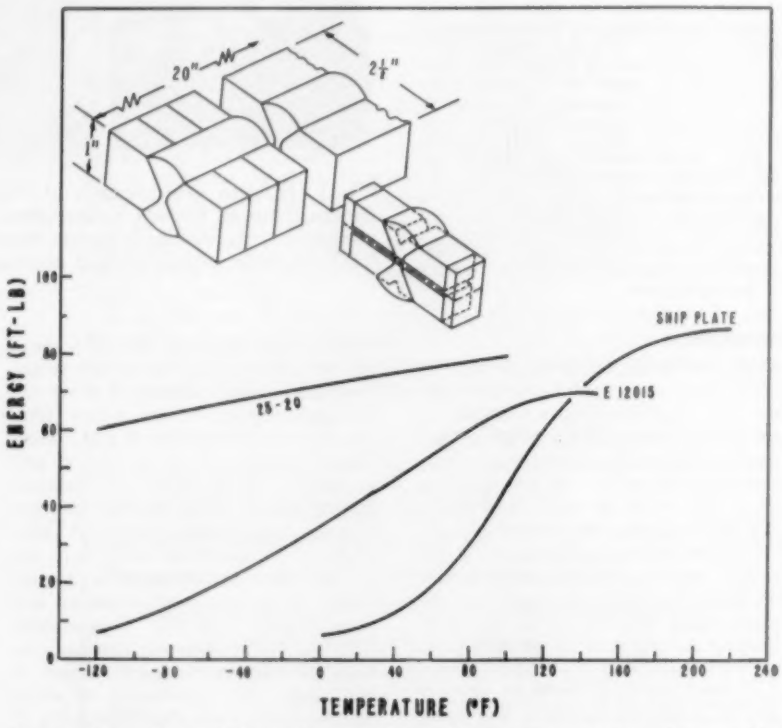

Fig. 4 Comparison of Charpy V curves for weld deposits and prime plate used in this investigation

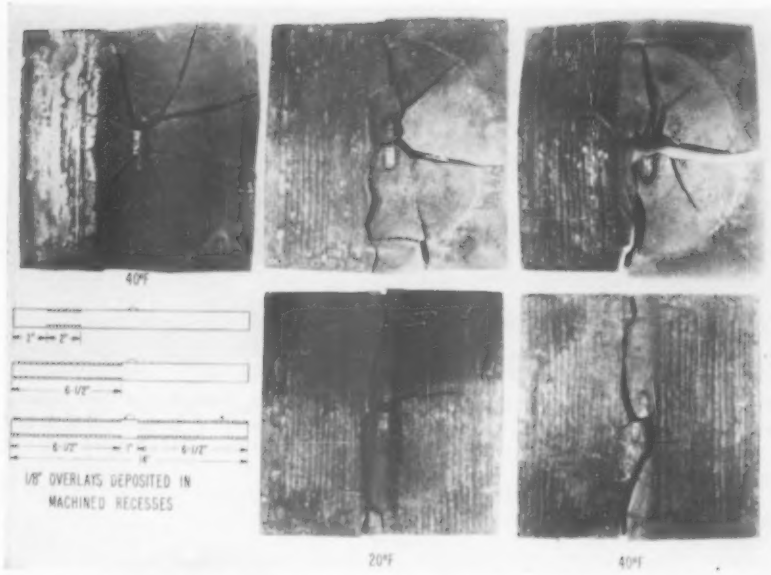

Fig. 5 Results of initial explosion crack-starter tests of specimens featuring E12015 weld deposits in machined grooves

Test Results—Fracture Stoppage

Initial tests using E12015 type electrodes were conducted with samples featuring 1/8-in. deep machined recesses with weld metal build-up (both surfaces of plate) to the original plate thickness. All welding was started at room temperature preheat and continued by maintaining a 100 to 200° F interpass temperature. Figure 5 depicts the test results at 20 and 40° F for three types tested. At these temperatures, the unwelded portions of the plate fractured readily but the overlay portions of the samples served effectively to arrest the brittle cracks. The ready susceptibility of the plate to exhibit brittle fractures at these temperatures suggested the possibility of a stress unloading mechanism which would preclude the full evaluation of the crack-arresting properties of the weld overlays. In addition, the machining of grooves or recesses in welded structures was not considered practical. Consequently, the balance of the investigation was limited to studies of samples featuring bead-on-plate weld overlays.

Further tests were performed with samples featuring 2-in. circular overlays (both surfaces of plate) around the periphery of the explosion test specimen. Figure 6 illustrates the results of such circular type specimens for the E12015 and 25–20 welds. A comparison with the control prime plate samples clearly indicates the effectiveness of the bead-on-plate overlays to arrest brittle fractures at 20 and 40° F. In the case of the circular welds, there could be no relief of the applied load by preferential cracking to one side of the plate which was considered as a possibility for the initial tests.

In these tests, the conditions were set to allow for the development of a rapidly running brittle crack with subsequent impingement in the weld region so as to determine the effectiveness of the bead-on-plate overlays in stopping brittle cracks. The effectiveness of the weld overlays to stop the cracks is considered to be due to a "shear drag" developed as the surfaces of the propagating crack generate heavy shear lips on entering the notch-ductile overlay zone. Figure 7 depicts the fracture surface of one of the cracks arrested at the circular weld zone which was stained with India ink, then cooled to dry-ice temperatures, and broken by bending. The inward movement of the crack at the center of the plate beneath the weld overlays and the stopping action due to shearing at the surface points of entry into the weld metal are clearly visible.

It is believed that additional studies are required to establish optimum widths of overlays necessary at various locations in welded structures and for various thicknesses of plates. The mechanics of the process suggest that the overlay width should be a function of plate thickness and relative crack-front acuity if resurfacing of the crack to the other side of the overlay is to be prevented.

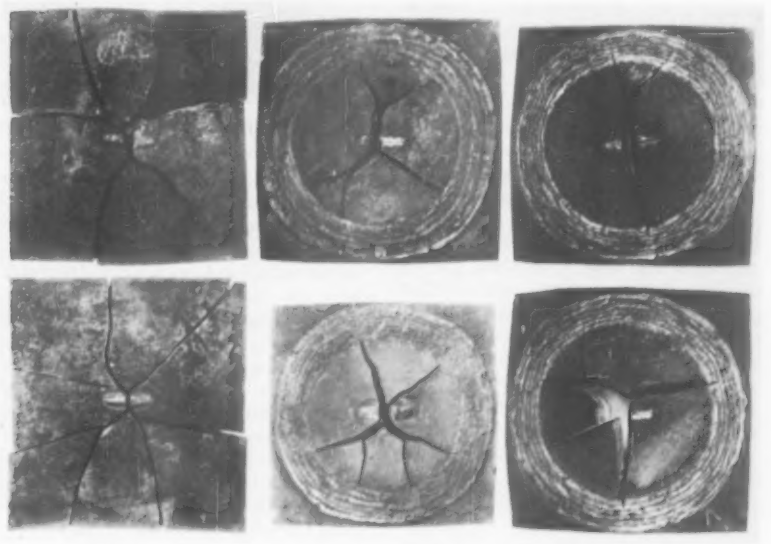

Fig. 6 Explosion crack-starter tests conducted at 40° F (top) and 20° F (bottom) of mild steel plate (left) E12015 circular weld overlay (center) and 25–20 circular weld overlay (right)

Fracture Initiation

Additional tests were conducted to determine the resistance to fracture initiation in the presence of weld overlays. For these tests, 1/8 in. was machined from each surface of the mild steel plate. Samples consisting of a core of brittle ship plate with surfaces of notch-tough weld metal were prepared by fully cladding both surfaces with a single layer of interlocking bead welds. The brittle crack-starter weld was then placed on top of the clad surface and the samples tested at 40° F. In addition to the standard explosion-loading condition test (in which offset distance and weight of explosive are adjusted to obtain only moderate bulging) other fully clad plates were tested with charges of increasing load to develop gross deformation. Figure 8 shows the results of these tests for fully clad plates of both E12015 and 25–20 weld metals. The extremely high order of resistance to fracture initiation in these samples is demonstrated by comparison with

the 40° F prime plate test shown in a similar oblique view in Fig. 9.

Summary Discussion

The results of these tests demonstrate that the cladding of a brittle steel with notch-tough weld metal imparts a high order of resistance to the initiation and propagation of brittle fractures. The improvement in the properties of the steel is derived from the presence of a surface layer of metal which fractures in a shear fashion at temperatures at which the surface layer of the base plate otherwise would have fractured in a brittle fashion. The change in the fracture mode of the surface from cleavage to shear precludes the initiation or propagation of high-speed fractures (brittle fracture).

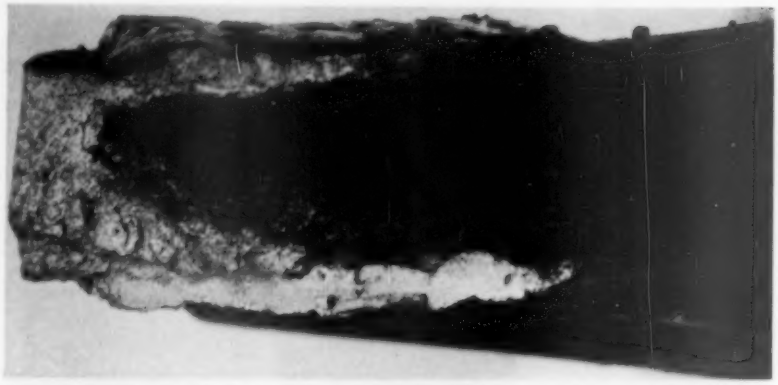

Fig. 7 Fracture surface of crack-end sample which was stained and then broken completely by bending at low temperature. Note inward movement of crack at center of plate; crack stopping due to shear-drag at the point of entry into the overlay

Fig. 8 Explosion crack-starter tests at 40° F of fully clad E12015 (top) and 25–20 (bottom) weld samples. Specimens on left show results of standard energy tests; center and right specimens depict results of increasing energy tests

The fact that high-speed, brittle fractures do not propagate under conditions where heavy surface shear lips are developed is evidenced by the absence of such fracture types in service failures. Similarly, explosion crack-starter tests have demonstrated that steel plates cannot be fragmented at temperatures at which heavy surface shear lips are developed. If the entire surface area of large plates could be clad in this manner, the ductility of the steel should be considered to be of high order (as illustrated in Fig. 8) at all temperatures at which the cladding fails only by shear.

General cladding for this purpose may be considered as practical in cases involving relatively small structures; however, it could not be considered economical for large structures. The major question raised by these tests involves the value of cladding when limited to small regions of large welded structures. If it is granted that high-speed fracture must terminate in regions of the structure involving steel of surface shearing quality, the question remains one of "how great a distance" of such a steel is needed in the path of the crack to prevent the fracture from crossing to the other side and then continuing to ultimate failure of the structure. This same question is faced in the use of notch-tough steel insert plates as welded crack arrestors in ships. There is no "one answer" to this question because the load characteristics of the structures must be considered. For example, the failure of the strength deck of a ship may so overload the remainder of the hull that a notch-ductile plate insert may be crossed in shear (due to high tearing forces) and the brittle fracture may continue on the other side of the insert. Obviously, an overlay of narrow width would not be expected to "hold the ship together" after the fracture has progressed across the strength deck.

The value of notch-tough overlays (or inserts of notch-tough steels) lies either in the prevention of initiation of the fracture or in stopping the propagation following short runs of the fracture. With this view, the application of the overlay method should be aimed at protecting points of connection or discontinuity, which are the usual points of initial failure in large welded structures. Over-all cladding of such positions should be used whenever possible with the aim of preventing initiation. In cases where this will be difficult or impractical, a ring-like cladding placed as close as possible to the point of possible initiation is suggested as a crack stopper. The method is considered practical for existing or new structures, and for emergency repairs in the field aimed at stopping the progress of short cracks.

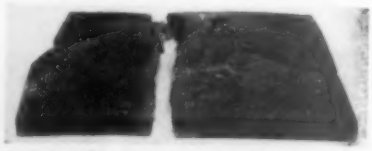

Fig. 9 Oblique view of 40° F explosion crack-starter test of prime plate

Acknowledgment

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by T. Griffin of Code 582, Bureau of Ships.

References

1. Puzak, P. P., Eschbacher, E. W., and Pellini, W. S., "Initiation and Propagation of Brittle Fracture in Structural Steels," THE WELDING JOURNAL, **31** (12), Research Suppl., 561-s to 581-s (1952).

2. Pellini, W. S., "Evaluation of the Significance of Charpy Tests," ASTM Symposium on Effect of Temperature on the Brittle Behavior of Metals with Particular Reference to Low Temperatures, Atlantic City, N. J., (June 28-30, 1953). (Spec. Tech. Pub. No. 158), Philadelphia; American Society for Testing Materials, 1954.

3. Pellini, W. S., and Eschbacher, E. W., "Ductility Transition of Weld Metal," THE WELDING JOURNAL, **33** (1), Research Suppl., 16-s to 20-s (1954).

4. Puzak, P. P., Schuster, M. E., and Pellini, W. S., "Crack-Starter Tests of Ship Fracture and Project Steels," *Ibid.*, **33** (10), Research Suppl., 481-s to 495-s (1954). Also supplementary note on "Crack-Starter Tests of Ship Fracture and Project Steels," *Ibid.*, **34** Research Suppl., 190-s (1955).

5. Williams, M. L., "Investigation of Fractured Steel Plates Removed from Welded Ships," Ship Structure Committee Report, National Bureau of Standards, Ser. No. NBS-3 (June 1951).

BRIEF ABSTRACT OF

LONGITUDINAL DEFORMATION OF LONG BEAM DUE TO FILLET WELDING

BY TOKUTANO SASAYAMA, KOICHI MASUBUCHI AND SIGERU MORIGUCHI

In the fabrication of T-bars or I-beams by fillet welding, the members may deform longitudinally because of the longitudinal shrinkage of weldment.

This research was performed for the purpose of investigating the effects of dimension of joint, the weight of deposited metal and other welding procedures on the longitudinal deformation.

Several T-bars and I-beams as shown in Fig. 1, were constructed by fillet welding flat bars to investigate the longitudinal deformation due to welding. The dimensions of the specimen used and other conditions of experiment are listed in Table 1.

The following measurements were made:

1. Deflection due to welding. Longitudinal deformation due to welding was measured by a dial gage at the state of welding each layer. The measurement of deformation was performed on several lines as shown in Fig. 1.

2. Change of deformation due to cutting after the completion of welding. If the specimen is cut longitudinally after the completion of welding, the deformation of specimen will change in

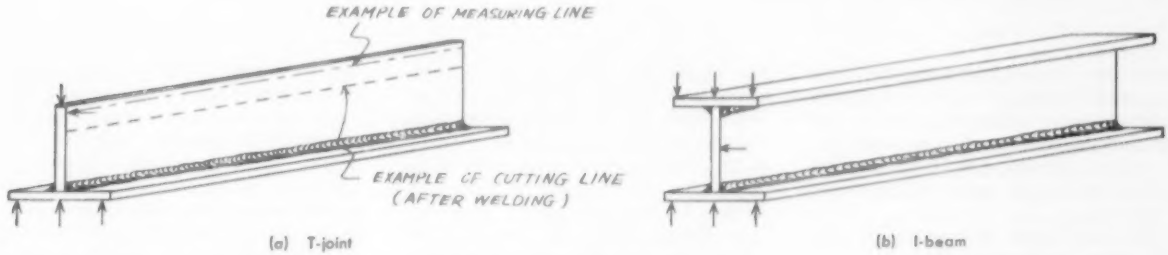
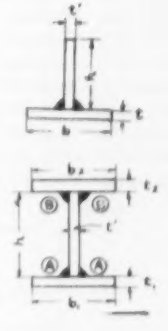


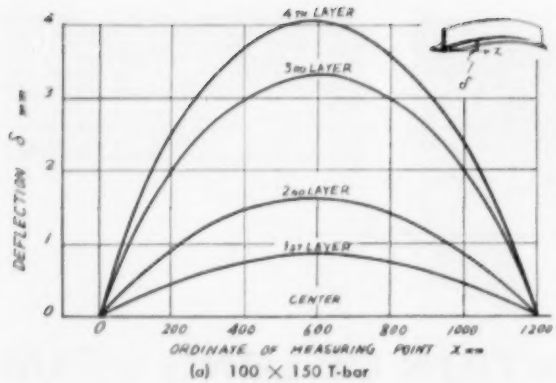
Fig. 1 Specimen (arrows show lines of measuring longitudinal deformation)

Table 1—Conditions of Experiment

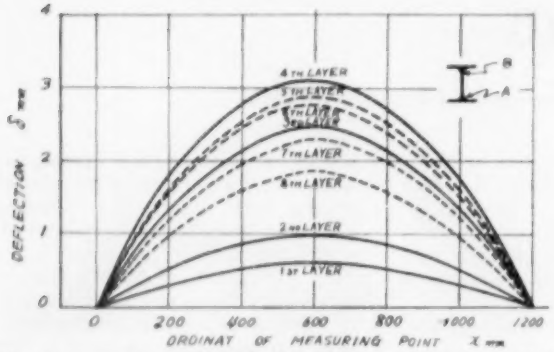
No. of specimen	Character of specimen	Size of specimen b, mm	t, mm	h, mm	t′, mm	Welding procedure: Test weld (A)	Preceding weld (B)
1	T-bar, 100 x 100 continuous weld	99	13	100	13	Continuous welding up to 4th layer	
2	T-bar, 100 x 150 continuous weld	100	13	148	13		
3	T-bar, 150 x 150 continuous weld	150	13	150	13		
4	I-beam, continuous weld Other flange: tack welded	$b_1 = b_2$ 100	t_1 12 t_2 13	150	13	Continuous welding up to 4th layer	Tack weld
5	I-beam, continuous weld Other flange: chain welded	$b_1 = b_2$ 100	$t_1 = t_2$ 13	150	13		Chain weld (4th layer)
6	I-beam, continuous weld Other flange: continuous welded	$b_1 = b_2$ 100	t_1 13 t_2 12	150	13		Continuous weld (4th layer)



NOTES: (1) Length of specimen, L = 1200 mm for all specimens. (2) The same specimen is used as specimens Nos. 4 and 6. Specimen No. 6 was welded after welding specimen No. 4.



(a) 100 × 150 T-bar



(b) I-beam, continuous weld both sides of fillet: 1st–4th layer, weld A; 5th–8th layer, weld B

Fig. 2 Examples of longitudinal deformation

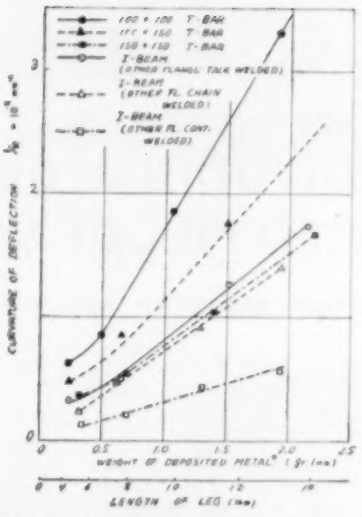

T-BEAM (OTHER FLANGE TACK WELDED)
I-BEAM (OTHER FL. CHAIN WELDED)
T-BEAM (OTHER FL. CONT. WELDED)
CURVATURE OF DEFLECTION
WEIGHT OF DEPOSITED METAL (gr/mm)
LENGTH OF LEG (mm)

Fig. 3 Relation between weight of deposited metal (length of leg) and curvature of deflection (exactly the weight of rod consumption per unit weld length)

accordance with the change of sectional area and moment of inertia of specimen. This change of deformation due to cutting by machining was also measured in order to determine the position of the acting point of apparent shrinkage force.

Typical forms of longitudinal deformation are shown in Fig. 2.

In a T-bar, the deformation gradually increases with the progress of welding (Fig. 2*a*). On the other hand, the phenomenon is somewhat different in case of fabricating an I-beam. In an I-beam (Fig. 2*b*), the deformation increases with the welding of the under side fillet (weld A), and it decreases with the welding of the other side (weld B). However, as the deformation due to the welding of second fillet is generally smaller than that of the first, the residual deformation remains even when the weight of deposited metal of both fillet welds is equal and the geometry of the joint is symmetric. This is due to the fact that the effective resisting area of joint differs between these two. That is, the upper flange does not effectively constrain the deformation at the welding of the under side of fillet as the upper flange is only tack welded to the web plate. However, both flanges effectively constrain the welding of upper side fillet as the lower flange is already completely welded to the web plate.

The relation between the weight of deposited metal (exactly the weight of rod consumption per unit weld length) or the length of leg and the curvature of longitudinal deformation for each specimen is shown in Fig. 3. In this figure the curvature of deformation is used as a measure of deformation, for it can be estimated from Fig. 2 that the curvature is nearly uniform along the length of specimen.

For all specimens the curvature of deformation increases in proportion to the weight of rod consumption per unit weld length which is proportional to the sectional area of deposited metal.

The curvature also varies in accordance with the geometry of joint. The largest deformation occurs in 100 × 100 T-bar, which has the least sectional area among these specimens. In I-beams, the specimen in which the other side of the fillet is tack welded produces the largest deformation, and the specimen in which the other side of fillet is continuously welded produces the smallest deformation.

These variations in deformation seem to be caused by the change of the resisting area of the specimen.

This figure also shows that, in general, the deformation at the welding of first layer is somewhat larger than what is estimated by the straight line determined by the welding of successive layers. This is due to the fact that the flange plate does not effectively restrain the deformation as it is not yet completely welded to the web plate.

MECHANICAL PROPERTIES OF MODIFIED TYPE 347 WELD METALS

A report by the Advisory Committee to the Atomic Energy Commission on Stainless Steels*

COMPILED BY R. DAVID THOMAS, JR., AND LORIN K. POOLE

ABSTRACT. Acceptable crack resistance and commercial usability were demonstrated by a standard (partially ferritic) Type 347 weld deposit, a Type 347CbTa weld deposit, a Type 308ELC weld deposit and two fully austenitic Type 347 compositions, one of which was modified by raising the carbon content to 0.12% and the other by raising the manganese to 5%. A standard composition modified to be fully austenitic was found to be unacceptable. Tensile and Charpy keyhole impact specimens were tested in the as-welded condition, after 8- and 100-hr heat treatments at 1100, 1300, 1550 and 1700° F and after 2-, 8-, and 24-hr heat treatments at 1950° F. The 0.505-in. diameter tensile properties of all compositions showed highest strength and lowest elongation when heat treated at 1100 and 1300° F. The optimum ductility was observed after heat treatments of 1700° F and higher. Optimum notched bar impact toughness at both room temperature and −320° F was observed after heat treatments at 1700° F and higher. The partially ferritic weld deposits showed greater tendency to embrittle after heat treatments at 1100 and 1300° F than did the fully austenitic Type 347 compositions. High notched bar impact values were obtained from the Type 308ELC weld deposit after all heat-treating conditions.

Introduction

Widespread reports of cracking and embrittling difficulties occurring during the welding and/or subsequent elevated temperature service of Type 347 stainless steel have been received from many fabricators. Since this alloy is of particular interest to the Atomic Energy Commission in connection with certain of its activities, the Commission is sponsoring a program directed to the development of improved weld metal compositions. The course of study followed was that established by the Advisory Committee for the Welding of Type 347 Steels, a subcommittee of the High Alloys Committee (Welding Research Council).

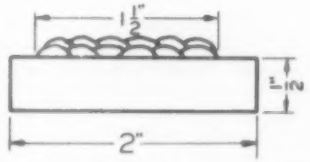


Fig. 1 End view of fissure test specimen showing method of depositing weld overlays

Before commencing an extensive research program, a survey of industry was made to confirm the original thinking on the most logical approach to this cracking and embrittling problem. The results of this survey[1] point out the many difficult-to-control conditions encountered when using the standard Type 347 electrodes, which depend on a small amount of ferrite in the weld deposit to prevent cracks and fissures. (For a discussion of the terms used to describe weld metal cracks, hot tears, and microfissures, the reader is referred to the survey.) This survey showed further that the ferrite in these electrodes rapidly transforms to sigma phase during exposure to service temperatures in the range of 1000–1650° F, rendering the weld deposit hard and brittle.

The development of a crack-resistant, fully austenitic composition would appear to overcome most, if not all, of the difficulties encountered when welding with the present partially ferritic compositions. It was also believed, and indicated by the survey, that if sigma phase is formed in a fully austenitic Type 347, the mechanism of the transformation, viz., austenite-to-sigma, would be considerably slower than the ferrite-to-sigma transformation which occurs in the standard composition.

Preliminary work prior to the establishment of the project sponsored by the Atomic Energy Commission had indicated that there was some hope of developing a fully austenitic composition, providing certain of the elements were controlled within narrow limits. The extent to which these controlled compositions would be free of cracking difficulties and embrittlement had not been fully evaluated. The chief object of this program was to determine

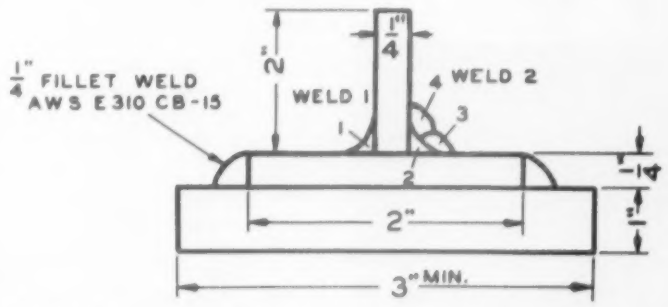


Fig. 2 End view of fillet weld test specimen showing sequence of deposition of beads in fillet welds and location of backing plate

* V. N. Krivobok, Chairman, International Nickel Co.; W. O. Binder, Electro Metallurgical Co.; F. W. Davis, Atomic Energy Commission; R. B. Gunia, U. S. Steel Corp.; M. A. Scheil, A. O. Smith Corp.; W. B. DeLong, E. I. du Pont de Nemours Co., Inc.; R. D. Thomas, Jr., Arcos Corp.; and L. K. Poole, Secretary, Arcos Corp.

Paper submitted to AWS by A. Tammaro, Assistant General Manager for Research and Industrial Development, Atomic Energy Commission, Washington, D. C.

Presented at 1955 AWS National Fall Meeting in Philadelphia, Pa., October 17–21.

Table 1—Composition and Designation of Electrode Weld Deposits*

Electrode	Type	C	Mn	P	S	Si	Ni	Cr	Cb	Ta	N_2	Ferrite, % calcd.†
A	19/9Cb	0.08	1.55	0.017	0.012	0.44	9.31	19.22	0.71	<0.03	0.044	7%
B	19/13Cb	0.087	1.49	0.017	0.013	0.33	13.02	19.09	0.74	<0.03	0.039	None
C	19/13Cb	0.115	1.32	0.019	0.013	0.45	13.06	19.09	0.70	<0.03	0.044	None
D	19/9CbTa	0.080	1.55	0.017	0.010	0.42	9.27	19.22	0.64	0.14	0.039	7%
F	19/10LC	0.036	0.73	0.021	0.018	0.26	10.53	18.92	..	...	0.044	4%
H	19/13MnCb	0.095	5.04	0.024	0.012	0.37	12.99	18.50	0.91	<0.03	0.037	None

Composition of core wires

Alloy No.	Electrodes	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	N_2
E2846T308	A & D	0.066	1.57	0.014	0.012	0.39	9.50	19.75	0.02	0.05	0.022
E2842T309	B, C, & H	0.063	1.59	0.013	0.010	0.35	13.24	19.60	0.02	0.05	0.019
E2847T308L	F	0.027	1.53	0.012	0.015	0.40	10.33	19.90	0.02	0.06	0.019

Composition of stainless steel base metals‡

For use in	Size	Type	C	Mn	P	S	Si	Ni	Cr	Cb + Ta
Fissure & impact tests	1/2 x 3 in	347	0.06	1.39	0.026	0.010	0.66	10.51	19.40	0.77
		304L	.024	1.55	.026	.016	.38	9.50	17.76	..
Fillet weld tests	1/4 x 2 in.	347	0.07	1.84	0.030	0.014	0.70	11.00	18.56	0.85
Butt weld tests	1 x 4 in.	347	0.07	1.60	0.030	0.021	0.62	10.74	17.92	0.84
		304L	0.026	0.66	0.019	0.012	0.65	8.43	19.01	..
Pipe weld tests	8 diam x 1 in. wall	347	0.059	1.37	0.024	0.013	0.46	10.39	17.55	0.60
Backup strips	1/4 x 1 in.	347	0.07	1.84	0.030	0.014	0.70	11.00	18.56	0.85
		304L	0.026	0.66	0.019	0.012	0.65	8.43	19.01	..

* Chemical analysis from nondilution weld pads made in accordance with ASTM-AWS specifications.
† Calculated from chemical composition according to Schaeffler diagram.
‡ Mill reports.

the ability of these or other fully austenitic compositions to resist cracking and embrittlement and to determine their suitability for service in corrosive media or in applications requiring high-temperature strength. This paper covers the portion of the program devoted to an evaluation of the ability of the electrodes to meet standard fabrication codes and the determination of the tensile and notch impact properties before and after exposure to elevated temperatures.

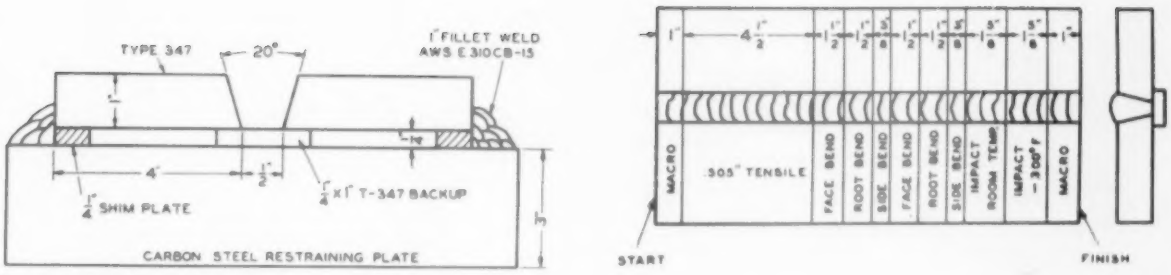
Electrode Compositions

The core wire and undiluted weld metal compositions of electrodes selected for the evaluation are shown in Table 1. Electrode composition "A" is chosen to represent typical Type 347 electrodes. Conforming to a recent revision of type compositions by the American Iron and Steel Institute, this composition is more properly designated Type 348, since it contains 0.10 max. tantalum. Composition "D" is a companion electrode manufactured with ferrotantalum-columbium, in which tantalum is not limited to 0.10 max. During the height of the columbium shortage in 1952, a few attempts were made to use ferrotantalum-columbium. The purpose of including composition "D" was to obtain a comparison between compositions manufactured with ferro-columbium and those with ferrotantalum-columbium. Preliminary work on this subject indicated little if any difference in properties.[3] Both compositions "A" and "D" were designed

Table 2—Fissure Test Specimens (Fissures Revealed by Etching and Bending)

Electrode	Base plate	Arcos fissures* Etching	Arcos fissures* Bending	Crane fissures* Etching	Crane fissures* Bending	A. O. Smith fissures* Etching	A. O. Smith fissures* Bending	Number of laboratories reporting defects: Etching	Number of laboratories reporting defects: Bending	Total
A	Carbon steel	No	No	No	No	No	No	0	0	0
	Type 347	No	No	No	1s, 3vs	No	No	0	1	1 / 1
B	Carbon steel	Yes	12m, 11s	No	1m, 5vs	No	No	1	2	3
	Type 347	Yes	3m, 4s, 12vs	No	3m, 6s, 10vs	Yes	10vs	2	3	5 / 8
C	Carbon steel	No	1m, 1s, 1vs	No	6vs	No	No	0	2	2
	Type 347	No	1s, 2vs	No	1s, 2vs	No	No	0	2	2 / 4
D	Carbon steel	No	No	No	No	No	No	0	0	0
	Type 347	No	No	No	No	No	No	0	0	0 / 0
F	Carbon steel	No	No	No	1-1, 10m, 21s	No	No	0	1	1
	Type 304-L	No	No	No	Many vs	No	No	0	1	1 / 2
H	Carbon steel	No	No	No	1vs	Yes	No	1	1	2
	Type 347	No	No	No	No	Yes	No	1	0	1 / 3
	Welding conditions		Arcos: 128–132 amp dc, 26–28 v		Crane: 115–120 amp dc, 23–28 v		A. O. Smith: 125–130 amp dc, 24–25 v			

* See note at bottom of Table 4.



For composition F Type 304L base metal was used

Fig. 3 Joint design and location of specimens in butt weld test

to give a partially ferritic weld metal structure containing 7% ferrite.

The earlier work on fully austenitic compositions clearly substantiated the work with other alloys, which indicated that cracking is largely influenced by the carbon and silicon contents in the weld metal.[3, 4, 5] When carbon is approximately 0.08%, silicon must be limited to a range so narrow that it is not commercially feasible. Composition "B" represents such an electrode, where both carbon and silicon are kept as low as possible while still achieving sound weld metal.

Cracking tendencies have been found to be very much reduced by increasing carbon content. With the higher carbon the permissible range in silicon is considerably widened. Composition "C" represents an electrode with higher carbon and silicon contents.

During the course of preliminary investigation of the cracking phenomena, it was observed that manganese has a pronounced influence on the cracking tendencies of the weld metal. The influence of manganese has been confirmed in subsequent publications by Egon Kauhausen on this subject.[6, 7, 8] Composition "H" was selected to represent a typical high manganese, fully austenitic structure.

In order to avoid delta ferrite in the as-welded structure, the nickel content of compositions "B," "C" and "H" has been raised from the normal 9 to 11% level to approximately 13%. All other elements in the 347 weld metal, except those specifically mentioned, were maintained as constant as possible.

The remaining composition, labeled "F," was intended to evaluate a non-columbium composition which presumably would be free from intergranular carbide precipitation by maintaining a low carbon content. The weld deposit composition from this electrode is typical in all respects, especially with regard to its carbon content (0.036%) and its ferrite content (4%), of commercial Type 308ELC electrode compositions.

The covering on all Type 347 electrodes was a commercial formulation, referred to as a "pure" lime type. It is distinguished from other lime type electrodes, many of which contain up to 10% titanium dioxide. The survey[1] conducted at the outset guided the decision to use this type because of its greater ability to resist cracking.

Although desirable from the cracking standpoint, the lime type covering could not be employed in the Type 308ELC composition because of carbon pickup. A commercial lime-titania covering was employed instead, giving a weld metal carbon content within the limits prescribed for commercial Type 308ELC electrodes.

PART I—WELD QUALIFICATION TESTS OF ELECTRODES

Object

Many ideas conceived and worked out in the laboratory where conditions are most favorable have not proved satisfactory in the field. For that reason the six electrodes described in the preceding section were subjected to a series of tests to determine their suitability for use under production conditions.

Procedure

Four sets of tests were devised which are typical of those employed by fabricators in the evaluation of electrodes. The composition of the stainless steel base metal used in these tests is found in Table 1. Details of the tests are as follows:

Fissure Test

This test comprises two-layer overlays on mild steel and on stainless steel. Six stringer pass beads are deposited side-by-side in each of the two layers as shown in Fig. 1. The top surface is then ground smooth, etched to detect cracks or fissures and finally bent with the weld metal in tension and again examined for cracks and fissures.

Fillet Weld Test

This is similar to standard fillet weld tests commercially prescribed in welding electrode specifications. Tests are conducted in the horizontal, vertical and overhead positions. As shown in Fig. 2, restraint is imposed by welding the fillet to a 1-in. restraining bar and a single-pass fillet is made on one side.

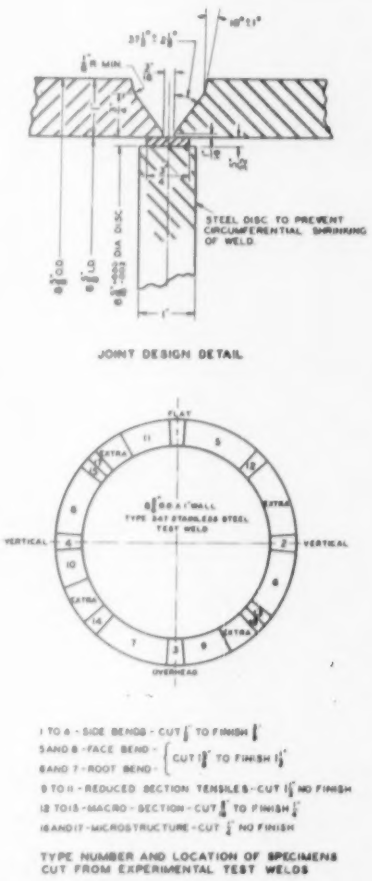

STEEL DISC TO PREVENT CIRCUMFERENTIAL SHRINKING OF WELD
JOINT DESIGN DETAIL
FLAT
VERTICAL
VERTICAL
OVERHEAD
EXTRA
TYPE 347 STAINLESS STEEL TEST WELD
1 TO 6 - SIDE BENDS - CUT TO FINISH
5 AND 6 - FACE BEND -
6 AND 7 - ROOT BEND -
CUT TO FINISH
9 TO 11 - REDUCED SECTION TENSILES - CUT NO FINISH
12 TO 15 - MACRO - SECTION - CUT TO FINISH
16 AND 17 - MICROSTRUCTURE - CUT NO FINISH
TYPE NUMBER AND LOCATION OF SPECIMENS CUT FROM EXPERIMENTAL TEST WELDS

Fig. 4 Joint design and location of specimens in pipe weld test

Fig. 5 Typical cross section of fillet weld taken at a weld crater

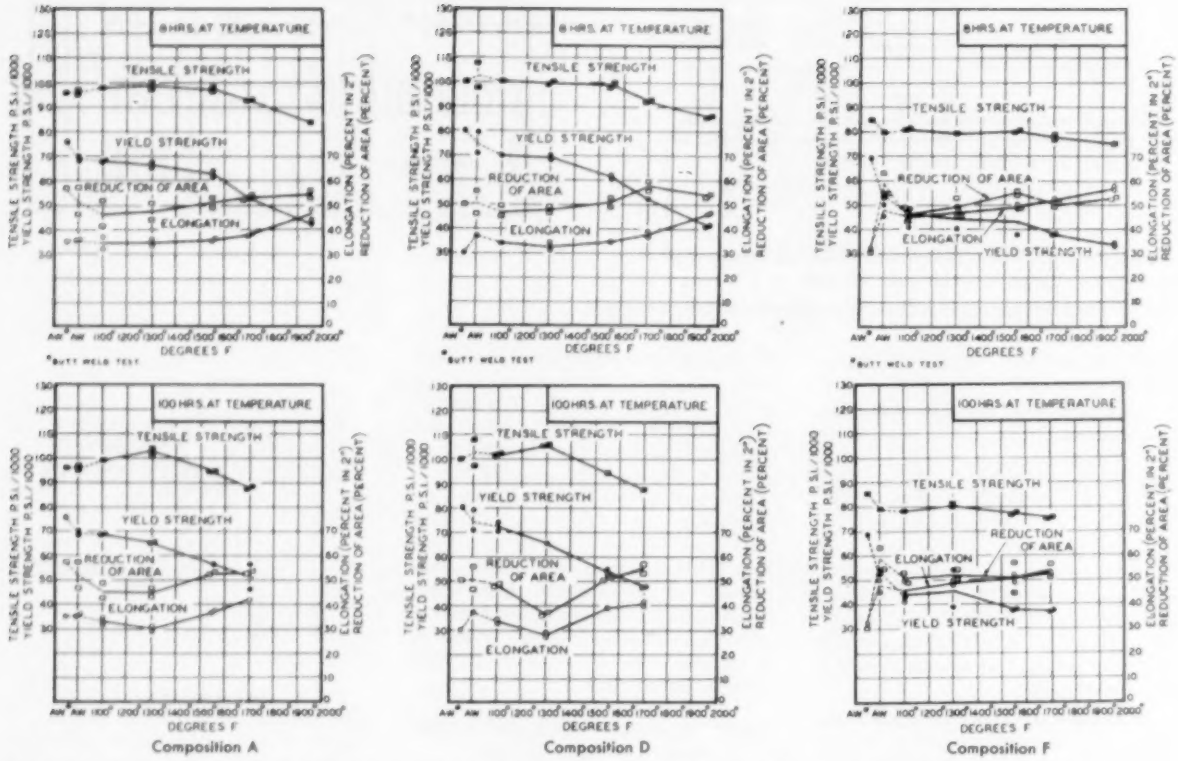


Fig. 6 Effect of 8- and 100-hr heat treatments on the tensile properties of partially ferritic compositions A, D and F

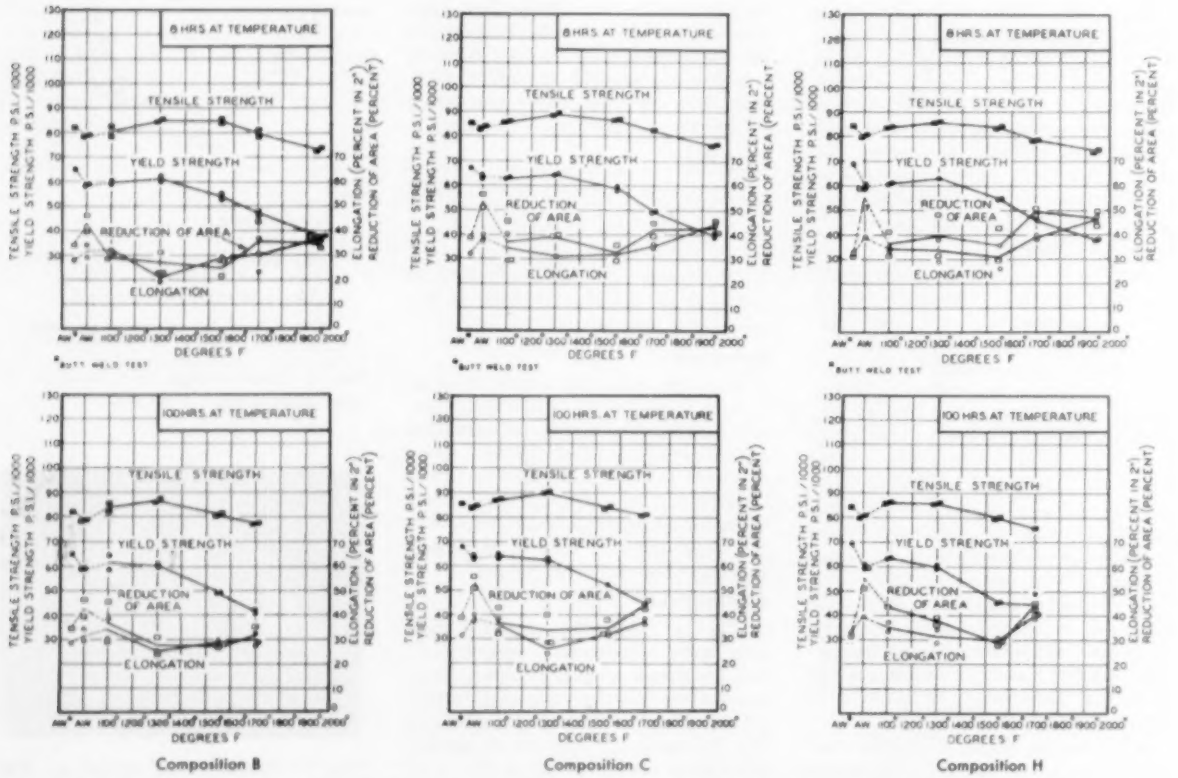


Fig. 7 Effect of 8- and 100-hr heat treatments on the tensile properties of fully austenitic compositions B, C and H

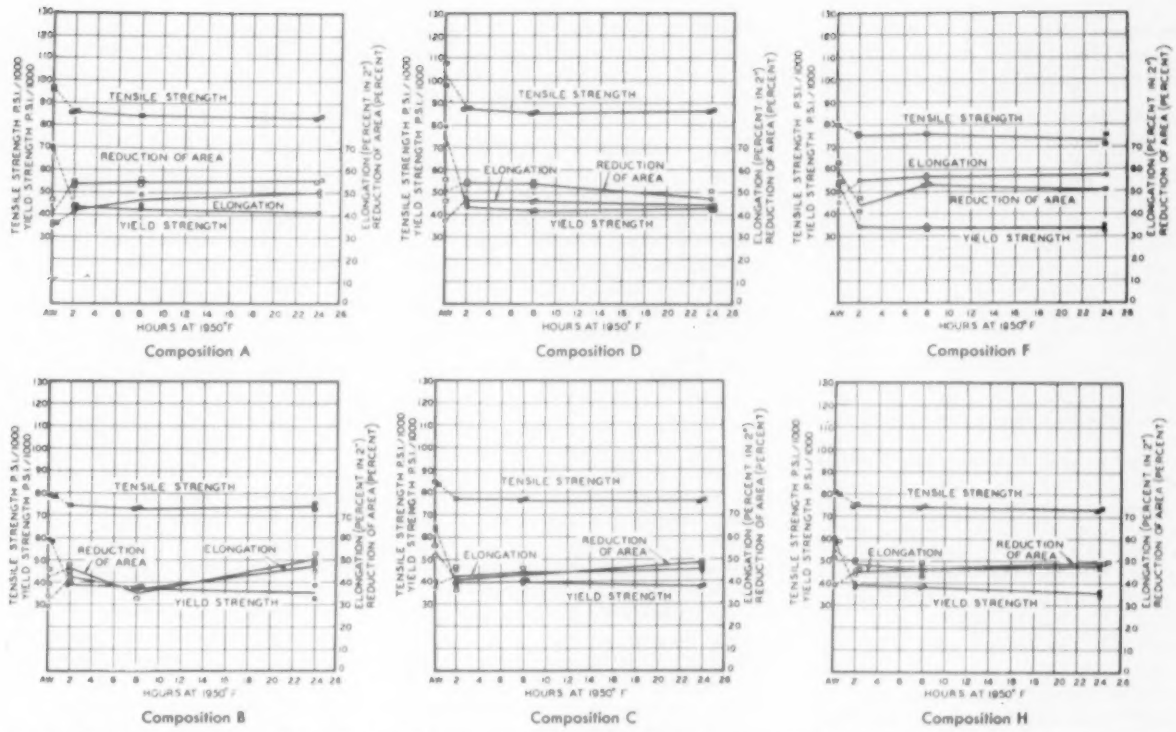


Fig. 8 Effect of time at 1950° F on the tensile properties of partially ferritic compositions (top) and fully austentic compositions (bottom)

followed by a three-pass fillet on the opposite side.

Butt Weld Test

This is an assembly comprising a butt weld between stainless steel plates 1 x 8 x 20 in. which have been previously restrained by fillet welding to a 3-in. thick carbon steel plate as shown in Fig. 3.

Pipe Weld Test

This test represents a simulated fixed position pipe weld restrained by the insertion of a steel disk to prevent shrinkage as shown in Fig. 4. At the time this test was conducted forged rings could be secured only in Type 347 steel, so the Type 308L composition (F) was not subjected to this test.

So that the evaluations of the electrodes would not be based solely upon the opinion or the observations of a single laboratory the various tests were subcontracted as follows:

Company	*Fissure test*	*Fillet weld test*	*Butt weld test*	*Pipe weld test*
Arcos Corp.	X	...	...	...
Crane Co.	X	...	X	...
Pittsburgh Piping and Equipment Co.	...	...	...	X
A. O. Smith Corp.	X	X	...	...

Results

Fissure Test

The results obtained from this test by the three participants are shown in Tables 2 and 3. Placing the various compositions in the order of the total number of specimens in which defects were observed, the relative rating given in the next table (right) is obtained.

On the basis of the elongations obtained before fissuring was observed, the following table helps to classify the relative performance of the various

	No. of Fissures Observed		
Composition	*Overlay on carbon steel*	*Overlay on stainless steel*	*Total*
D	0	0	0
A	1	0	1
F	1	1	2
H	1	2	3
C	2	2	4
B	5	3	8

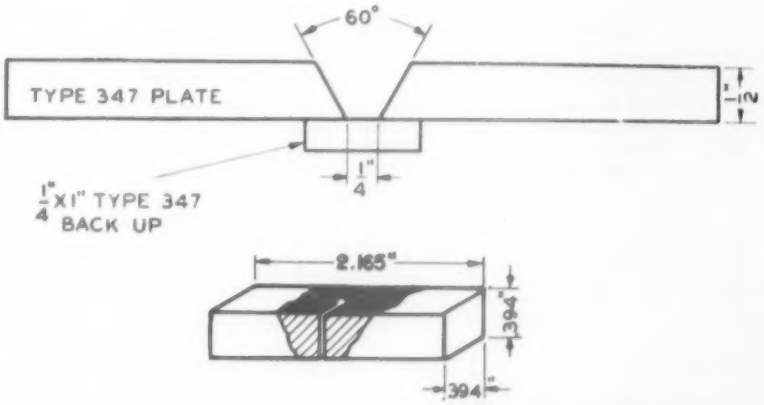


Fig. 9 Joint design and location of notch in impact specimens (base metal used for composition F was Type 304L)

electrodes. The listing of elongations reported below is the average of the reported elongations in 1/2-in. gage length:

Overlay on carbon steel		*Overlay on stainless steel*	
Electrode	*Elongation, % in 1/2 in., avg.*	*Electrode*	*Elongation, % in 1/2 in., avg.*
H	38	H	44
B	31	C	42
C	24	D	40
D	19	A	39
F	18	F	38
A	16	B	34

The results of these tests indicate that fully austenitic compositions are somewhat more susceptible to fissuring than partially ferritic compositions. Of the three fully austenitic compositions, "C" and "H," containing high carbon and high manganese, respectively, are less susceptible than "B." Although fissures may be present, the fully austenitic grades show greater ductility before failure than the partially ferritic grades. This is especially true of the composition "H" overlay on carbon steel.

Fillet Weld Test

A satisfactory usability rating was obtained for all electrodes in all positions, with the exception of electrodes "F" and "H" in the vertical position. In these two cases the investigator reported only fair performance, with a comment on electrode "F" that there was some tendency to pinch out and that in the case of electrode "H" the metal was somewhat more fluid than the others.

The observations on the fillet weld test are not unexpected. Electrode "F," as noted above, has a coating containing substantial quantities of titanium dioxide. General industry experience has always shown that such coatings are less satisfactory in the vertical position as compared with those containing little or no titanium compounds.

The "fluid" condition of the electrode "H" weld metal characterizes a combination of properties, such as surface tension, viscosity, cohesion and adhesion. In the vertical welding position the operator must overcome the greater tendency of the metal to roll down forming irregular surface appearance. This effect has been observed in other high manganese welding electrodes, such as Type 307 used for welding armor plate.

An example of the appearance of the cross section of the welds is shown in Fig. 5. A total of 90 such cross sections were observed, from which only seven showed any evidence of defect after macroexamination under binoculars. Three-fifths of the sections were intentionally made through craters, and all but one of the defects were found in these craters. Six crater defects were found, one each in welds deposited in the three positions using electrodes "B" and "H." Also fissures and slight porosity were noted when welding with electrode "F" in the vertical position.

Butt Weld Test

Radiographs of finished butt welds taken after the removal of the backup strips showed no defects in welds made with electrodes "A," "B," "C," "D" or "H." Approximately ten scattered spherical voids were observed in the weld made with electrode "F." The difference is presumed to have been caused by the different type of coating used on the extra-low carbon electrode.

Fusion-line defects were observed in all plates after dye-penetrant inspection in the root area after the backing strip had been removed by machining, grinding and etching. This observation is not unexpected, since this type of defect has been reported frequently[9] in highly restrained joints where backing strips are employed. The defects were somewhat more extensive in the case of a weld made with electrode "F." In all cases the dye-penetrant indications are attributed to incipient basal root crack formations in the junction of the weld, base metal and backing strip.

Ultrasonic inspection was employed in an attempt to identify internal cracks or fissures. Very slight indications were obtained on the Reflectoscope in certain areas of all of the welds. When specimens cut from these areas were tested, there was no evidence of defects, leaving some doubt as to whether the slight indications actually pointed to a defect. Fissures which

Table 3—Elongation of Fissure Test Specimens Before Fissuring or Cracking

		Arcos				*Crane*				*A. O. Smith*			
			Elongation, %				*Elongation, %*				*Elongation, %*		
Electrode	*Base plate*	*Bend angle*	*1/2 in.*	*1 in.*	*2 in.*	*Bend angle*	*1/2 in.*	*1 in.*	*2 in.*	*Bend angle*	*1/2 in.*	*1 in.*	*2 in.*
A	Carbon steel	70°	19	16	12	101°	20	19	17	20°	10	7	5
	Type 347	173°	36	36	31	202°	50	48	41	180°	30	28	27
B	Carbon steel	74°	24	22	18	183°	46	40	33	55°	22	19	13
	Type 347	175°	37	38	33	175°	36	34	31	180°	30	27	26
C	Carbon steel	80°	23	23	18	184°	30	29	28	45°	18	17	13
	Type 347	187°	39	38	36	203°	52	48	39	180°	34	28	25
D	Carbon steel	68°	24	19	14	111°	30	27	21	30°	8	8	7
	Type 347	173°	37	35	31	205°	50	46	39	180°	32	30	27
F	Carbon steel	149°	17	19	23	86°	18	18	13	40°	18	13	9
	Type 304-L	169°	35	33	30	205°*	46*	45*	38*	180°	32	27	25
H	Carbon steel	171°	35	38	30	186°	40	35	33	180°	40	36	32
	Type 347	173°	42	43	32	200°	56	50	39	180°	34	30	26

Rating based on elongation in 1/2 in.

	Arcos base plate		*Crane base plate*		*A. O. Smith base plate*	
	Carbon steel	*Stainless*	*Carbon steel*	*Stainless*	*Carbon steel*	*Stainless*
1	H	H	B	H	H	H
2	B	C	H	C	B	C
3	D	B	C	A	C	D
4	C	D	D	D	F	F
5	A	A	A	B	A	A
6	F	F	F	F†	D	B

* Fissures observed on prebending to 60–80°. Elongation measured after bending to 205°.
† Rating assumed, see *.
< Indicates equal elongation in 1/2 in.

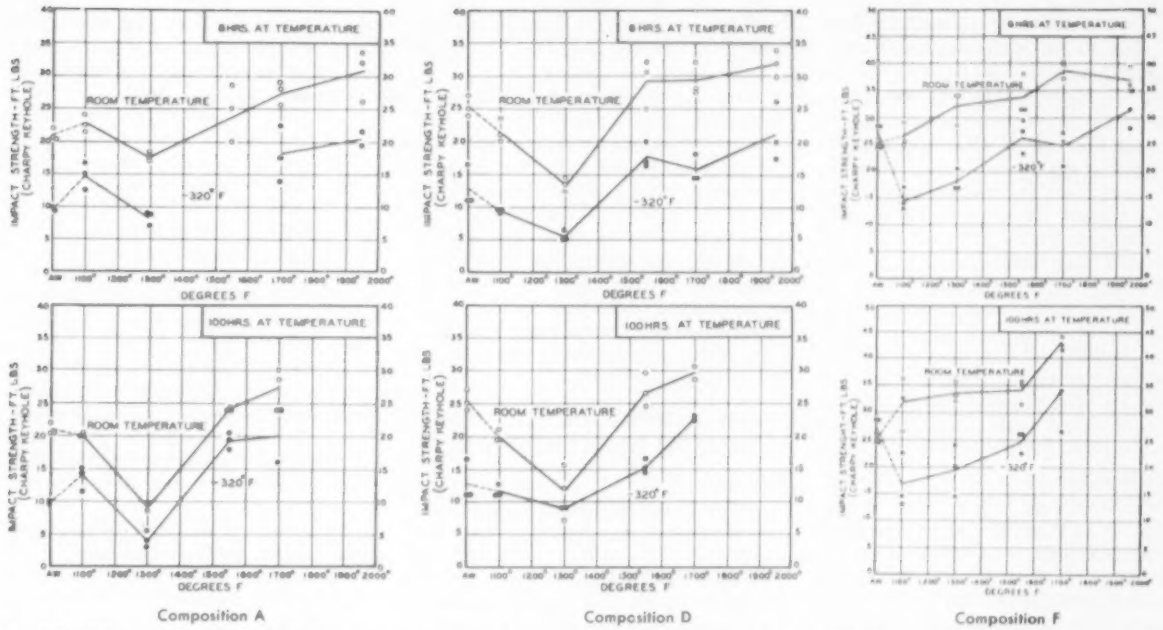


Fig. 10 Effect of 8- and 100-hr heat treatments on the notched bar impact strength of partially ferritic compositions A, D and F (tests performed by the International Nickel Co.)

were later observed on the surface of the bend test specimens were not observed by the ultrasonic inspection techniques employed, again leaving doubt as to the suitability of this technique for identifying fissured weld metal.

All-weld-metal tensile specimens and transverse impact specimens were machined from the butt welds. The results from these specimens are incorporated with the values described in Parts II and III.

The results of free face bend, free root bend and guided side bend tests are given in Table 4. The following listing of the duplicate specimens indicates the relative merit of the electrode compositions as measured by the bend tests:

Composition "F" would have headed the listing except for the $^{5}/_{32}$-in. defect

Composition	*Free face bends*		*Free root bends*		*Guided side bends*	
D	OK	OK	OK	OK	OK	OK
A	OK	OK	OK	OK	OK	OK
F	OK	OK	OK†	OK	OK	OK
C	NG*	OK	OK†	OK	OK	OK
H	OK†	OK†	OK†	NG‡	OK	OK
B	OK†	OK†	NG	NG	NG	OK

* Failed due to edge tear.

† These samples showed a minimum of 36.5% elongation in $^{1}/_{2}$ in., but did not bend to 180°.

‡ Failed at fusion line.

Table 4—Bend Test Results from 1-In. Butt Welds

	Free face bend			*Free root bends*			*Guided side bends*	
Electrode	*Angle of bend*	*Elongation in 1 in.*	*Weld metal fissures**	*Angle of bend*	*Elongation in $^{1}/_{2}$ in.*	*Weld metal fissures**	*Angle of bend*	*Weld metal fissures**
A	180†	45.5	1vs	180	32.0	1m, 7vs	180	0
	180	39	0	180	30.0	6vs	180	0
B	143‡	36.5	1s, 5vs	71§	6.0	1s, 3vs	45‡	1—l, 3s, 2vs
	153‡	42.0	6m, 6s, 3vs	73§	4.0	2s	180	2vs
C	127‖	24.5	0	167§	38.0	2—l, 6vs	180	1—l, 3s, 3vs
	158‡	57.5	2s, 1m	180§	40.0	4vs	180	2vs
D	180	32.0	0	180	30.0	1s, 2vs	180	2vs
	180	30.0	1vs	180	32.0	1vs	180	0
F	180	36.0	1vs¶	180**	40.0	1s, 4vs	180	0
	180	44.0	1vs	180§	38.0	0	180	0
H	166‡	41.0	2vs	152§	40.0	1—l, 4vs	180	2s, 2vs
	168‡	44.5	1—l, 1m, 3s	106§	18.0	0	180	0

* l—large, $^{1}/_{16}$ in. and over; m—medium, $^{1}/_{32}$–$^{1}/_{16}$ in.; s—small, $^{1}/_{64}$–$^{1}/_{32}$ in.; vs—very small, under $^{1}/_{64}$ in.

† Base metal tear.

‡ Transverse tear in weld metal.

§ Fusion zone tear.

‖ Edge tear.

¶ Small fissure in HA zone.

** $^{5}/_{32}$-in. opening caused by slag.

Tests conducted in the laboratories of the Crane Co., Chicago, Ill.

caused by slag in one root bend specimen. The free bend specimens marked NG failed to meet the frequently specified 30% ductility requirement; in the case of composition "C" the failure was due to an edge tear and in the case of composition "H" the failure was due to a defect at the line of fusion. In either of these cases the failure could have been caused by improper machining of the test specimen or could be attributed to an operator fault and would be grounds for retest since the companion specimen passed the test. In the case of composition "B," however, the elongations were only 4 and 6% and the failure occurred in the weld. One side bend specimen failure occurred at a 45° bend angle in one of the two composition "B" specimens.

Pipe Weld Test

The root pass of all welds was examined by the fluorescent-penetrant method and no root cracks were observed in any of the welds. Radiographic examination showed a 1/16-in. slag spot at one point in the weld with composition "H" and a 1/8-in. slag spot in the weld with composition "B."

The results of testing specimens machined from pipe welds are found in Table 5. The number of defects observed in the bend specimens was very few and appeared to a greater degree in compositions "B," "C" and "H" and only rarely in compositions "A" and "D."

Of all of the free bend specimens tested, only one with electrode "C" showed an elongation below the usual 30% minimum requirement. One of the four side bend specimens of electrode "H" showed objectionable fusion line tears.

The higher strength, partially ferritic electrodes "A" and "D" invariably caused the transverse tensile specimens to fail in the base metal. The ultimate strength values reported for composition "D," however, indicate that either the base metal in this case has an unusually low strength or the values reported are in error. A hardness measurement of the base metal wherein the breaks occurred did not show evidence of a difference in strength in the forged rings employed.

PART II—EFFECT OF HEAT TREATMENT ON TENSILE PROPERTIES

Object

Of the various metallurgical tools for evaluating materials the tensile test is one of the simplest. This test has therefore been applied to determine the stability of the weld metal structures when subjected to elevated temperatures, which may occur either during postheat treatment or under service conditions.

Procedure

All-weld-metal tensile samples were prepared in accordance with ASTM Specification A298–55T, welding in grooves of mild steel plate which had been buttered with two layers of weld metal.

To assure uniform heat treatment the weld deposit was cut from the grooves and machined into 2/4-in. diameter bars prior to heat treatment. Duplicate samples of each composition were heat treated for each of the following times and temperatures.

(*a*) As-welded.
(*b*) 1100° F for 8 and 100 hr.
(*c*) 1300° F for 8 and 100 hr.
(*d*) 1550° F for 8 and 100 hr.
(*e*) 1700° F for 8 and 100 hr.
(*f*) 1950° F for 2, 8 and 24 hr.

In order to eliminate the effect of cooling and heating rates which have been reported to affect the mechanical properties,[1] the heat treatments were made as nearly isothermal as possible. The specimens were placed in a furnace which had been heated to the desired temperature, were held for the specified length of time and were cooled by water quenching.

After heat treatment the bars were machined to 0.505-in. diameter tensile specimens and tested at room temperature in accordance with ASTM Specification E8–52T. The average crosshead speed through the elastic stress range was about 0.05 in. per minute. The yield strength was measured at 0.5% extension under load.

Results

The tensile data have been presented graphically in Figs. 6, 7 and 8. The duplicate specimens show values which check one another in all except six determinations. In these six exceptions, five of which measure elongation or reduction of area, the influence of fissures

Table 5—Pipe Weld Test Specimens

Electrode	*Flaws in side bend specimens*	*Elongation of free bend specimens, %*		*Transverse tensile specimens*		*Average Rockwell B hardness of weld*		*Average % ferrite†*	
		Root	*Face*	*Strength, psi*	*Location of failure*	*Root*	*Face*	*Root*	*Face*
A	(1) None	36N	45	89,500	Base metal	98.9	90.9	4.7	5.8
	(2) None	38N	45N	91,300	Base metal				
	(3) None	...	...	89,750	Base metal				
	(4) None								
B	(1) None	38N	34	86,500	Base metal	97.8	83.8	0	0
	(2) Eight small	42	37	88,950	Weld & base				
	(3) None	...	...	86,600	Weld				
	(4) Two small								
C	(1) Three small, edge tears	22	30	93,600	Base metal	96	86.8	0	0
		37.5N	33	87,950	HA zone				
	(2) One small	...	...	87,250	HA zone				
	(3) None								
	(4) None								
D	(1) None	36N	39N	76,000*	Base metal	99.1	92.9	4.3	6.8
	(2) None	33N	40	78,450*	Base metal				
	(3) One small	...	...	78,500*	Base metal				
	(4) None								
H	(1) None	33	37	87,200	Base metal	96.1	84.9	0	0
	(2) Two 1/16-in. tears	37N	37	85,700	Base metal				
	(3) One small	...	...	85,500	Weld & base				
	(4) One small								

N—No defects evident after completion of bend.
* Values questioned because hardness measurements show no evidence of a difference in strength of the individual forged rings used.
† By Magnegage.
Tests conducted in the laboratories of Pittsburgh Piping & Equipment Co.

Table 6—Fissures Observed in Tensile Specimens

			—1100°—		—1300°—		—1550°—		—1700°—		—1950°—			
Electrode	*Size*	*AW*	*8 hr*	*100 hr*	*8 hr*	*100 hr*	*8 hr*	*100 hr*	*8 hr*	*100 hr*	*2 hr*	*8 hr*	*24 hr*	*Total*
A	1/16 in. or over	0	0	0	0	0	0	0	0	0	0	0	0	0
	Under 1/16 in.	0	0	1	1	0	0	1	1	0	0	0	6	10
B	1/16 in. or over	0	0	1	0	0	1	0	1	0	0	0	0	3
	Under 1/16 in.	1	19	5	24	16	18	9	21	11	13	10	8	158
C	1/16 in. or over	0	0	0	0	0	0	0	1	0	0	0	0	1
	Under 1/16 in.	2	12	10	7	9	19	13	7	3	11	8	4	107
D	1/16 in. or over	0	0	0	0	0	0	0	0	0	0	0	0	0
	Under 1/16 in.	0	8	2	5	3	1	2	3	3	2	5	3	37
F	1/16 in. or over	0	0	0	0	0	0	0	0	0	1	0	0	1
	Under 1/16 in.	0	1	0	2	2	1	2	0	1	5	2	10	26
H	1/16 in. or over	0	1	1	0	0	0	0	1	0	0	0	0	3
	Under 1/16 in.	0	10	7	7	12	8	10	8	6	2	8	6	84

in the specimen explains the anomalous behavior. The remaining exception is an unbelievable value of ultimate tensile strength occurring in composition "H" which was treated 100 hr at 1700° F. In all six of these cases the line drawn on the graph ignores the anomalous figure.

In all compositions the highest strength levels are obtained after heat treatment at 1300° F, corresponding to a condition producing the lowest elongation results. In all-heat-treatment conditions the level of elongations is well above 30% for all compositions, excepting in the case of composition "B" in the temperature range of 1100 to 1700° F and in compositions "C" and "D" subjected to 100 hr at 1300° F. Composition "F" shows remarkable elongations, well over 40%, throughout the range of heat treatment.

While there appears to be a dip in the elongation curve for practically all metals treated in the range of 1100 to 1550° F, the drop is not so marked as might have been expected, especially in the partially ferritic compositions "A" and "D." The 100-hr treatment at 1300° F was expected to produce an embrittlement in these two compositions which would be easily observed in the elongation determination.

Since this was not the case, the specimens were tested with an Alnico magnet from which it was determined that complete transformation of the magnetic ferrite to nonmagnetic sigma phase had not occurred even after the 100-hr heat treatment.

The graphs in Fig. 8 for the most part show little effect on the tensile properties by prolonged heating at 1950° F. As would be expected, the initial 2-hr treatment reduces strength and increases ductility. Continued heating at this temperature increases the elongation further with very small reductions in strength.

Table 6 gives the number of fissures observed in the various specimens after tensile testing. As expected, the fully austenitic compositions and especially composition "B" showed the greatest number of fissures. It is interesting to note that the fissures appear to increase in the specimens which have had a postheat treatment, especially those treated in the range of 1300 to 1700° F.

The appearance of fissures does not necessarily indicate that a defect existed prior to testing. Although concrete evidence is not available, it is believed that fissures may represent localized failure occurring during plastic deformation of the specimen.

Over 98% of the fissures observed in the specimens were less than 1/16 in. long; moreover 85% were less than 1/32 in. long. In most cases, the fissures were not observed in the austenitic welds "C" and "H" until after reaching

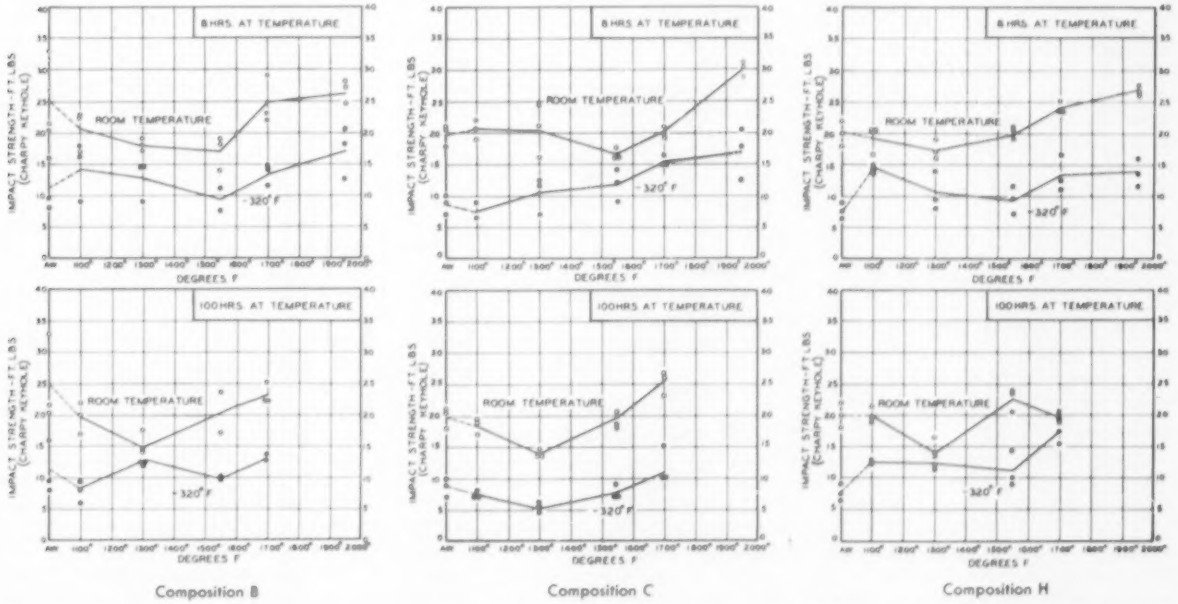
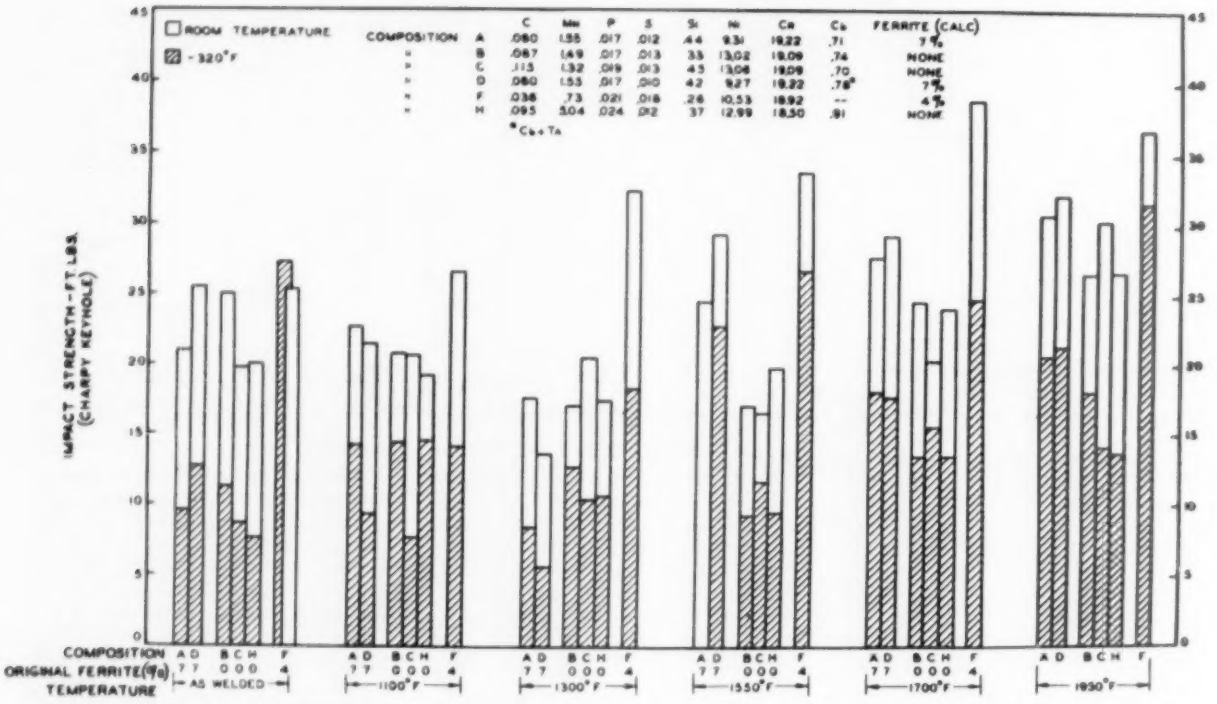


Fig. 11 Effect of 8- and 100-hr heat treatments on the notched bar impact strength of fully austenitic compositions B, C and H (tests performed by the International Nickel Co.)



COMPOSITION	C	Mn	P	S	Si	Ni	Cr	Cb	FERRITE (CALC)
A	.060	1.55	.017	.012	.44	9.31	19.22	.71	7%
B	.067	1.49	.017	.013	.33	13.02	19.09	.74	NONE
C	.115	1.32	.019	.013	.45	13.06	19.09	.70	NONE
D	.060	1.55	.017	.010	.42	9.27	19.22	.78*	7%
F	.036	.73	.021	.018	.26	10.53	18.92	--	4%
H	.095	5.04	.024	.012	.37	12.99	18.50	.91	NONE

*Cb + Ta

Fig. 12 Effect of 8-hr heat treatments on the notched bar impact strength of modified Type 347 weld deposits (tests performed by the International Nickel Co.)

elongations which exceed those at which the partially ferritic welds would fail.

PART III—EFFECT OF HEAT TREATMENT ON NOTCH IMPACT PROPERTIES

Object

The tendency for embrittlement to occur in ductile materials can usually be demonstrated clearly by notched bar impact tests. One object of the study was to detect embrittling tendencies when the weldments were subjected to elevated temperatures either during service or during a fabrication postheat treatment. Another object was to evaluate the suitability of weld compositions for use in structures for low temperature (below −300° F) applications. The results reported in this section are intended to give an appreciation of the properties of the various compositions after the same series of heat treatments employed in the previous section, at both room temperature and low temperatures.

Procedure

Charpy keyhole notched bar impact specimens were cut from butt welds made in $\frac{1}{2}$-in. stainless plate which had been previously restrained by fillet welding to a carbon steel strong-back. The joint design and orientation of the notch in the impact specimen are shown in Fig. 9. Type 347 base metal was used for the five columbium-bearing electrodes and Type 304L was used for the weld with electrode "F." The heat treatments were carried on in a manner identical to that described for the all-weld-metal tensile tests in the previous section. The specimens were rough machined prior to heat treatment. During heat treatment, however, the scale loss at some of the temperatures was of sufficient magnitude to cause the specimens to be undersize when finish machined; these bars were discarded. For this reason, it was impossible to obtain triplicate specimens for each testing temperature as was originally planned. All tests at both room temperature and at low temperature (−320° F) were conducted at the Bayonne, N. J., laboratories of the International Nickel Co.

Results

The data obtained are shown graphically in Figs. 10 and 11. In most cases the individual determinations agree with one another within ±5 ft-lb of the average. This amount of scatter is not unusual in the testing of weld metal whose heterogeneity causes a somewhat wider scatter than normally is encountered in wrought austenitic steels.

Unlike the tensile tests, the notch impact specimens of compositions "A" and "D" clearly indicate the embrittling effect of a 1300° F postheat treatment, especially during the 100-hr exposure time. Though incomplete, the transformation of ferrite to sigma in these two compositions is clearly evident. The influence of heat treating on the fully austenitic compositions does not reduce the room temperature impact strength as markedly as in the partially ferritic compositions. The whole level of results, however, is somewhat lower in the fully austenitic compositions than that obtained with compositions "A" and "D" except after heat treatments at 1100 and 1300° F where the fully austenitic compositions show equal or better results than the partially ferritic compositions. The remarkable performance of composition "F" suggests that this weld metal would be especially adaptable for applications where high notch impact values must be obtained.

A comparison of the various compositions is found in Figs. 12 and 13. In every case the noncolumbium extra-low-carbon composition "F" gives superior performance. The fully austenitic compositions appear to be somewhat better at room temperature and at very low temperatures than the partially ferritic compositions when heat treated at the embrittling temperature of 1300° F. Of the various columbium-bearing compositions somewhat less embrittlement is encountered with the fully austenitic compositions than with those containing ferrite.

For low-temperature applications Fig. 14 shows that the best performance among the columbium-bearing compositions is obtained after an annealing

treatment at 1950° F. Partially ferritic compositions are preferable to ferrite-free compositions from the standpoint of low-temperature notch impact properties. In most cases prolonged holding at 1950° F improves the impact values; the exceptions are probably caused by data scatter and have no metallurgical significance.

The photomicrograph in Fig. 15 shows the well-known transformation of ferrite-to-sigma in partially ferritic composition "A." After 100 hr at 1300° F, the transformation is incomplete, but other experiments[10] have shown that prolonged exposure eventually causes complete transformation giving continuous patches which show very low notch impact values.

SUMMARY AND PRACTICAL CONSIDERATIONS

With the exception of composition "B," all of the electrodes subjected to the evaluation tests reported above may be considered suitable for production welding and for fabricating structures to withstand stress and impact conditions normally encountered by austenitic steel weldments. Some electrodes, however, are more limited in their application than others. The limitations of the various electrodes will be discussed each under its separate section.

Electrode Composition "A"

This composition is intended to be representative of present commercial Type 347 electrodes. Because it contains an average of 7% ferrite in the as-welded condition, it is highly resistant to cracks and fissures. During exposure extending for any substantial length of time in the temperature range of 1000 to 1700, the ferrite transforms to sigma causing notch brittleness, an increase in tensile strength and a loss in tensile ductility. Prolonged heating, such as might occur in service, will further reduce the notch toughness and tensile ductility to values below those reported for the 100-hr tests at temperatures of 1100, 1300 and 1550° F.

This composition is therefore recommended as the most suitable of the columbium-bearing varieties for facility in fabricating crack- and fissure-free weldments under restraint. The mechanical properties are excellent in the as-welded condition, but if a postheat treatment is required the temperature should be raised to at least 1700° F. The rate of heating and cooling will be dictated by other considerations, such as section thickness, but this study indicates that the importance of specifying a minimum time in the range between 1100 and 1700° F should be carefully considered. Where a weldment is to be exposed to the temperature at which ferrite transforms to sigma, a prior anneal at 1950° F will dissolve and spheroidize the ferrite, thus minimizing the embrittling effect.

If a columbium-bearing weld metal should be required for a low temperature (−300° F) application, composition "A" will be suitable if postheat treated at a temperature of 1700° F or higher.

Electrode Composition "B"

This fully austenitic composition is not considered commercially feasible. Despite the severe restrictions in carbon and silicon, it gave the poorest performance with respect to cracks and fissures during fabrication tests. By comparison with the other fully austenitic compositions "C" and "H" it has no advantages in mechanical properties.

Electrode Composition "C"

This relatively high carbon fully austenitic composition was one of the two best fully austenitic compositions as indicated by the fabrication qualification tests. In applications where a ferrite-free composition is essential and high carbon (up to 0.12%) is not considered objectionable for other reasons, such as highly corrosive service, this

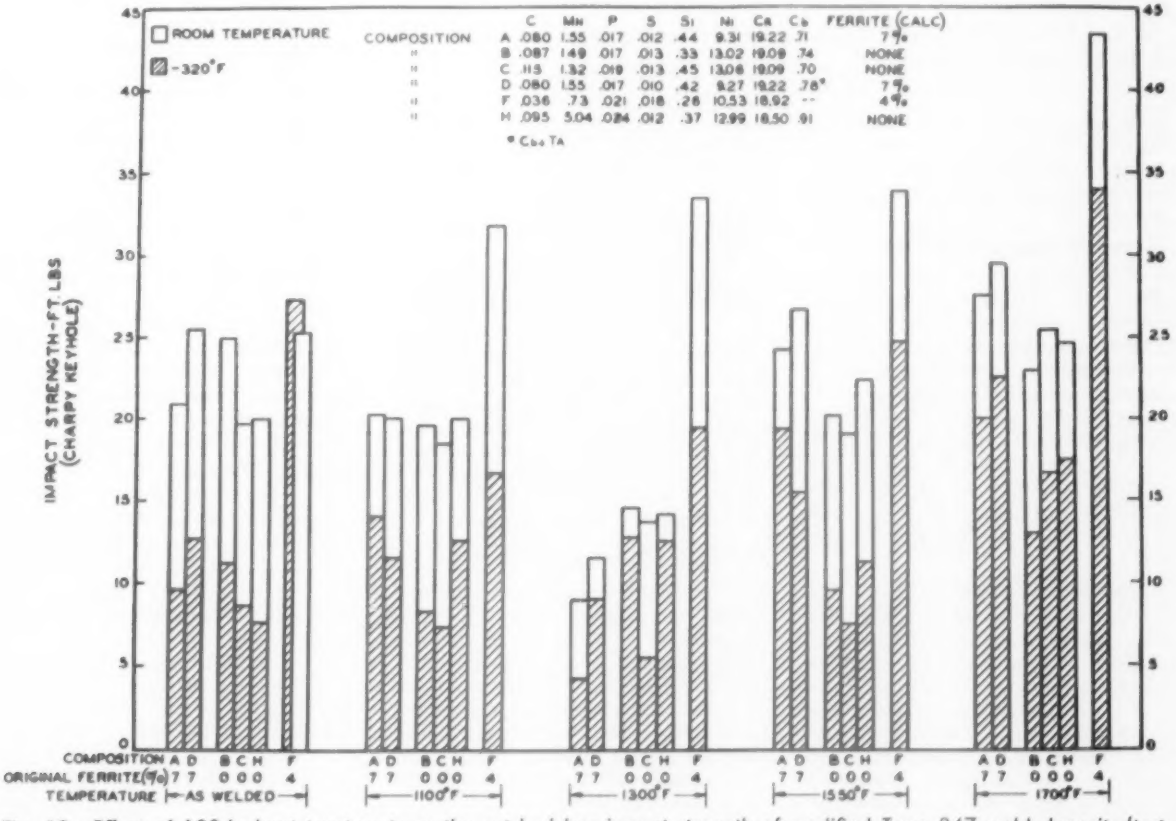


Fig. 13 Effect of 100-hr heat treatments on the notched bar impact strength of modified Type 347 weld deposits (tests performed by the International Nickel Co.)

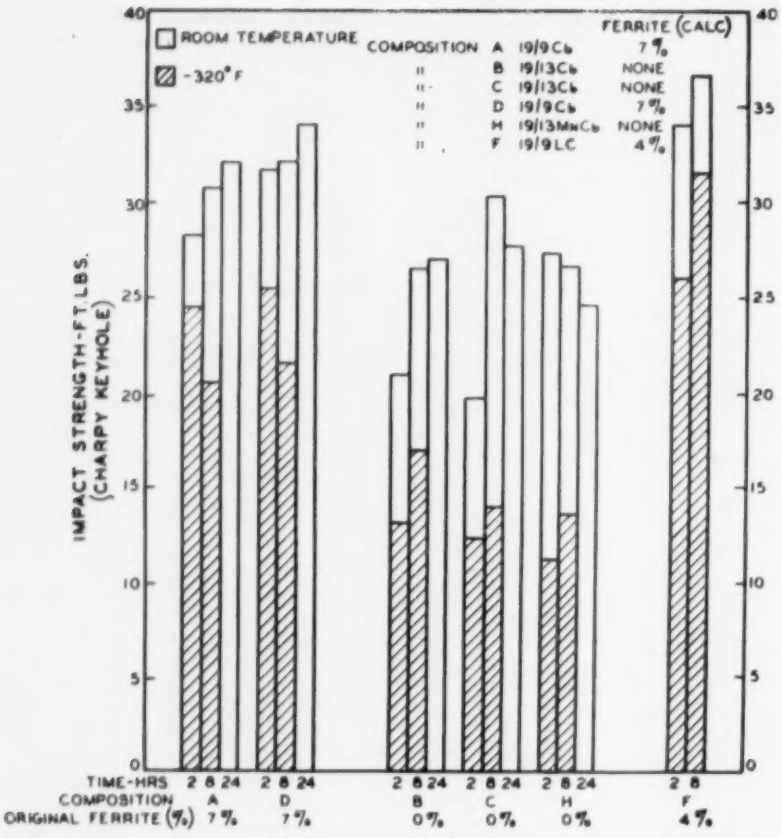

ROOM TEMPERATURE
-320° F
COMPOSITION
FERRITE (CALC)
A 19/9Cb 7%
B 19/13Cb NONE
C 19/13Cb NONE
D 19/9Cb 7%
H 19/13MnCb NONE
F 19/9LC 4%
IMPACT STRENGTH-FT LBS. (CHARPY KEYHOLE)
TIME-HRS 2 8 24 2 8 24 2 8 24 2 8 24 2 8 24 2 8
COMPOSITION A D B C H F
ORIGINAL FERRITE (%) 7% 7% 0% 0% 0% 4%

Fig. 14 Effect of time at 1950° F on the notched bar impact strength of modified Type 347 weld deposits

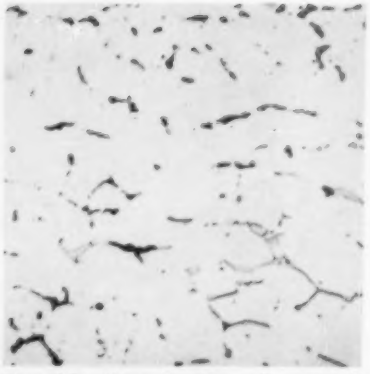


Fig. 15 Microstructure of composition A weld deposit after heat treatment of 1300° F for 100 hr. Ferrite (light) and sigma (dark) are observed in an austenite matrix. Etchant: Kalling's-Mod. Murakami's. Magnification: 1000 ×. (Reduced by 1/3 upon reproduction.)

composition might well be considered. The high carbon content may be found to be advantageous in applications requiring strength at elevated temperatures.

Electrode Composition "D"

This partially ferritic electrode, a companion of "A," has demonstrated that tantalum can be substituted for a part of the columbium without altering the mechanical properties. Where one appears to be slightly superior to the other under various circumstances, these differences are felt to be too small to be attributable to the greater amount of tantalum. The comments relating to composition "A" above, therefore, apply equally to composition "D."

Electrode Composition "F"

Being a noncolumbium composition, the properties of this electrode are difficult to compare with the others. From the standpoint of facility in fabrication, it differs from all others because of the titania content of its coating. This is made necessary in order to achieve very low carbon contents in the weld metal, but causes some difficulty in vertical welding and in slag entrapment in restricted areas. Despite the fact that this electrode suffers by comparison with the others in some of the fabrication tests, nevertheless the electrode is considered satisfactory for commercial use even under adverse fabrication conditions.

Its chief characteristics are high ductility and toughness even after prolonged exposure to elevated temperatures. It is especially suitable for applications requiring toughness at room and very low (−300° F) temperatures. Its room temperature strength is substantially below that of the columbium-bearing weld metals, but equal to that of the Type 304L wrought stainless steel on which it would normally be applied.

Electrode Composition "H"

This high (5%) manganese fully austenitic composition is very similar to composition "C" in its mechanical properties and in its cracking and fissuring tendency. In vertical welding, the high manganese makes the weld metal a little more fluid; though slightly greater difficulty may be expected, it is nevertheless acceptable for fabrication operations.

If a ferrite-free weld composition appears to be required and carbon must be limited, the introduction of 5% manganese appears to be suitable to control fissuring tendencies. Fissures are more prevalent than in the partially ferritic compositions, but they are usually very small and in most cases do not appear until after surpassing elongations which would have caused failure in the partially ferritic grades. Crater cracks may be expected to a greater degree than when using partially ferritic compositions. For applications requiring complete freedom from crater defects, removal of craters is mandatory. This practice is frequently followed even for the less sensitive partially ferritic weld in cases where severe service conditions are to be encountered.

The absence of ferrite makes this composition suitable for applications in elevated temperature service where sigma embrittlement must be minimized.

In common with the other columbium-bearing fully austenitic grades, composition "H" does not appear to be particularly suitable for use in low temperature (−300° F) applications in any condition of heat treatment.

Work in Progress

A program of tests to evaluate the corrosion resistance of these weld metals is under way. This program includes the same six electrode compositions, which have been subjected to the same postheat treatments as those reported above.

A statistical analysis of the influence of the individual elements on the cracking tendency of fully austenitic weld compositions is also being conducted.

Preliminary tests have been conducted on the stress rupture properties of compositions "F" and "H." A more complete high-temperature program is under consideration.

Acknowledgments

This work has been possible by the joint collaboration of all members of the Advisory Committee to the Atomic Energy Commission on the Welding of Stainless Steels. The work of the following companies who contributed data for the phases of the project reported in the paper is gratefully acknowledged: Crane Co., A. O. Smith Corp., International Nickel Co., Pittsburgh Piping and Equipment Co. and the Electro Metallurgical Co.

Bibliography

1. Poole, L. K., "The Incidence of Cracking in Welding Type 347 Steels," THE WELDING JOURNAL, **32** (8), Research Suppl., 403-s to 412-s (1953).

2. Thomas, R. David, Jr., "Tantalum Partly Replaces Columbium Content of Electrodes," *Iron Age*, **167**, 109–111 (April 5, 1951).

3. Campbell, Hallock C., and Thomas, R. David, Jr., "The Effect of Alloying Elements on the Tensile Properties of 25-20 Weld Metal," THE WELDING JOURNAL, **25** (11), Research Suppl., 760-s to 768-s (1946).

4. Carpenter, O. R., and Jesson, N. C., "Some Factors Controlling the Ductility of 25% Cr–20% Ni Weld Deposits," *Ibid.*, **26** (12), Research Suppl., 727-s to 741-s (1947).

5. Rozet, David, Campbell, Hallock C., and Thomas, R. David, Jr., "Effect of Weld Metal Composition on the Strength and Ductility of 15% Cr – 35% Ni Welds," *Ibid.*, **27** (10), Research Suppl., 481-s to 491-s (1948).

6. Kauhausen, E., and Vogels, H. A., "Development of Electrodes for Welding of Austenitic Steels for High Pressure Vessels," *Schweissen und Schneiden*, **4** (2), 35–40 (1952).

7. Kauhausen, Egon, "Welding of Austenitic Steels for High Pressure Boiler Plants," *Proceedings of the First World Metallurgical Congress, 1951*, pp. 429–435, published by ASM (1952).

8. Kauhausen, Egon, and Vogels, H. A., "Successful Manufacture and Use of All-Austenitic Welding Electrodes," *Metal Progress*, **67** (1), 129–136 (1955).

9. Mueller, R. A., and Root, W. B., "Inert-Arc Welding Technique for Eliminating Backing Rings in Piping," THE WELDING JOURNAL, **32** (3), 205–216 (1953).

10. Poole, Lorin K., "Sigma—An Unwanted Constituent in Stainless Weld Metal," *Metal Progress*, **65** (6), 108–112 (1954).

BRIEF ABSTRACT OF

STUDIES ON THE SHRINKAGE AND RESIDUAL WELDING STRESS OF FUNDAMENTAL CONSTRAINED JOINT

BY HIROSHI KIHARA AND KOICHI MASUBUCHI

The ring type constrained specimens (see accompanying figure) are used especially for the purpose of studying the effect of welding techniques on the transverse shrinkage and residual stress of the fundamental joint, as one of the studies which are being made to survey the effect of welding procedures on the shrinkage, distortion and residual stress of welded joint and to obtain the fundamental principles on the method of fabrication of welded ships and wagons, etc.

The X-shaped bevel is cut in the radial direction and the welding is performed on that position. This type of specimen is used for the purpose of simplifying the analysis of the motion of the plate edges during the progress of welding and the distribution of residual stress.

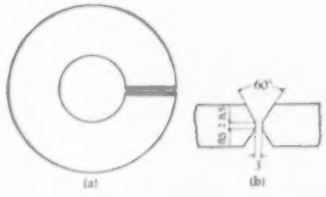
As the degree of constraint will be changed by changing the outer and the inner radius of the specimen, 7 types shown in the accompanying table were prepared (total number is 30).

The results obtained from this experiment are summarized as follows with reference to mean shrinkage:

(1) *General.* In the multiple layer welding the mean shrinkage u gradually increases with the progress of welding. There exists a linear relation between the mean shrinkage u and the logarithm of the rod consumption per the unit weld length w or that of the weight of deposit metal per unit weld length Wd.

Namely

$$u = a + b \log w$$



Type of Specimen

(2) *Effect of Rod Diameter.* The benefit of using the larger electrode to minimize the shrinkage cannot be expected when the first layer is not welded with the larger electrode.

(3) *Effect of Weaving Motion.* In this experiment the specimens welded by the weaving method have produced less shrinkage than that welded by the single bead.

(4) *Effect of Peening.* Shrinkage decreases by peening.

(5) *Effect of Type of Electrode.* The low-hydrogen type electrode has produced an especially large shrinkage.

(6) *Effect of Degree of Constraint.* In every series, the specimen which has the greater degree of constraint has always produced less shrinkage than that which has the less degree of constraint.

(7) *Submerged Arc Welding.* Submerged arc welding produces much less shrinkage—nearly one-third—than the hand weld.

Type and Standard Size of Specimens

Type of specimen	*Outer diameter, mm*	*Inner diameter, mm*	*Weld length, mm*	*Plate thickness, mm*	*Number of specimens prepared*
106	1000	600	200	19	
96	900	600	150	19	
86	800	600	100	19	3
73	700	300	200	19	5
63	600	300	150	19	9 (6 are fully annealed)
53	500	300	100	19	3
42	400	200	100	19	4
				Total	30

Dr. Hiroshi Kihara is president of the Japanese Welding Engineering Society and Prof. of Tokyo University

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STUDIES ON THE BRITTLE FAILURE OF TANKAGE STEEL PLATES

F. J. FEELY, JR., M. S. NORTHUP, S. R. KLEPPE AND M. GENSAMER

As the result of the failure of two large oil storage tanks in England in the spring of 1952[1] the Esso Research and Engineering Co. (formerly Standard Oil Development Co.) undertook an investigation into the causes of these failures. Emphasis was placed on the development of experimental procedure to simulate conditions at the time of the failures. There was and is no desire to develop or advocate another acceptance test for steel, but rather a desire to study the progress of brittle fractures under conditions as nearly like those in real structures as possible and to correlate the results of such studies with the values obtained from conventional tests.

The progress on this program has been reported,[2, 3] and a practical solution to the tank building problem has been recommended.[4] The present paper constitutes a final report.

Experimental Technique

Brittle fracture can be considered a process made up of two stages, first the initiation or nucleation of the fracture and then its propagation or growth. One could hope to find a solution to the problem through a study of either one or both of these stages. Practical considerations of fabrication problems lead to the opinion that in an actual tank it is possible to reduce the probability of initiation, but not completely to avoid it. For this reason it was decided to study crack propagation, eliminating as nearly as possible the influence of starting effects.

T. S. Robertson[5] had already developed a testing technique to study the conditions under which running cracks are arrested. Robertson started a crack by impact in a knob on the edge of a plate in tension, having cooled the knob with liquid air to minimize the impact energy required to start the crack and also to provide a temperature gradient, heating the opposite edge of the plate when necessary. He determined, at various stress levels, the temperature in the plate at which the crack stopped, and thus a relationship between the stress and temperature required to maintain a running crack. He verified his results with a temperature gradient in the plate by "go or no-go" tests at uniform temperature.

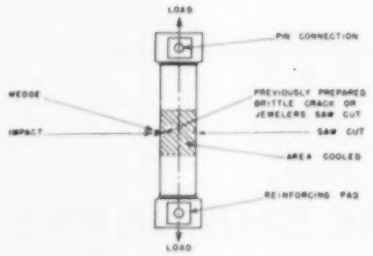


Fig. 1 Typical test specimen

The testing procedure developed by the authors differed somewhat from Robertson's and has been described in some detail in an earlier paper[2]. Briefly it consists of starting a crack by driving a wedge into a previously prepared transverse notch in a long tensile specimen, as shown in Fig. 1. When the specimen at a particular and uniform temperature is loaded to a sufficient stress this crack will propagate across the entire width of the plate. If the stress is too low, or for a particular stress the temperature is too high, the crack will not propagate. By varying the stress at a constant temperature, or the temperature at a constant stress, it is possible by "go or no-go" tests, to establish a point on a curve, of which the curve in Fig. 2 for steel A-1 in Table 1 is typical. In the stress-temperature region below this curve, cracks will not propagate; while in the region above the curve the test produces complete failure.

The impact on the wedge is supplied by a rivet shot from a gun using a 45-caliber cartridge with variable powder charge. In the test work already reported[2, 3] the notch used was a brittle crack produced by subcooling a localized area around the saw cut, then striking the wedge to drive a short crack. The specimen during this operation was bent as a simple beam to give a tensile stress at the edge of the plate, so as to produce a short, straight transverse crack. In later tests, the precracking was avoided. A smaller wedge angle was found to be more effective, and when used with a jeweler's saw cut eliminated the necessity for precracking.

Effect of Impact Energy

A series of tests in the low-temperature range in which the impact was varied (temperature and size of plate constant) to determine its effect on the

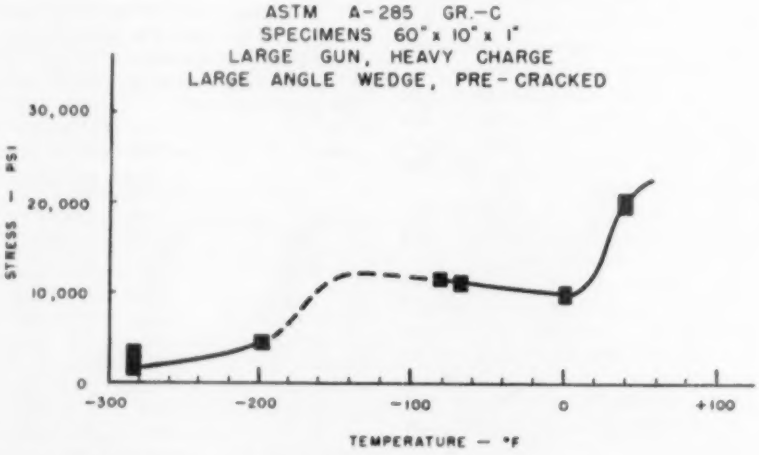


Fig. 2 Breaking stress vs. temperature

F. J. Feely, Jr. is Assistant Director, M. S. Northup is Senior Engineering Associate and S. R. Kleppe is Engineer of the Design Division, Esso Research and Engineering Co. M. Gensamer is Professor of Metallurgy, School of Mines, Columbia University, and Consultant to the Esso Research and Engineering Co.

Presented at the 1955 AWS National Fall Meeting held in Philadelphia, Pa., Oct. 17-21.

stress for propagation produced the curves of Fig. 3. For Curve *B* (large wedge angle, precracked) above a certain impact value the stress for failure is nearly independent of impact energy. For Curve *A* (small wedge angle, jeweler's saw cut) the stress for failure is still decreasing as impact energy is increased, presumably because the more effective wedge alters the stress distribution more than does the less effective wedge and prevents achieving a steady value in a plate of this size. Observe that both curves extrapolate to the same stress at zero impact energy, ignoring the upswing at very low impact energies resulting from a stress impulse peak inadequate to initiate fracture.

It would be expected that the energy delivered to the plate by the wedge would affect the stress required to start the crack and would also affect the stress required to keep the crack running, unless the plate were very large. If for a given size of plate the propagating stress reaches a steady value as the wedge energy is increased, then the limiting value of this stress as the plate is increased in size should be the stress required for propagation in a very large structure. However, this limiting stress value will not be reached in specimens of limited size because the impact energy also influences the stress level in the plate while the crack is running. This effect decreases the stress required to keep the crack running for anything but the infinite plate. Hence, the limit stress is to be determined by extrapolating not only to the infinite plate but at the same time to infinitesimal wedge energy.

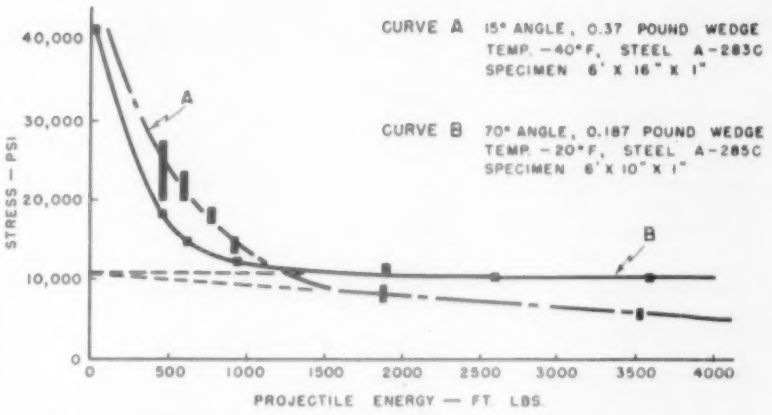


Fig. 3 Impact effect below Esso Brittle Temperature

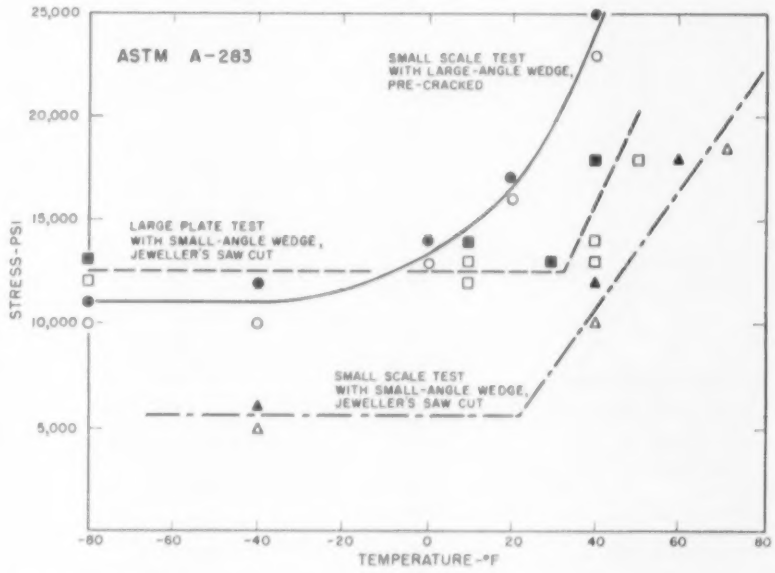


Fig. 4 Size effect

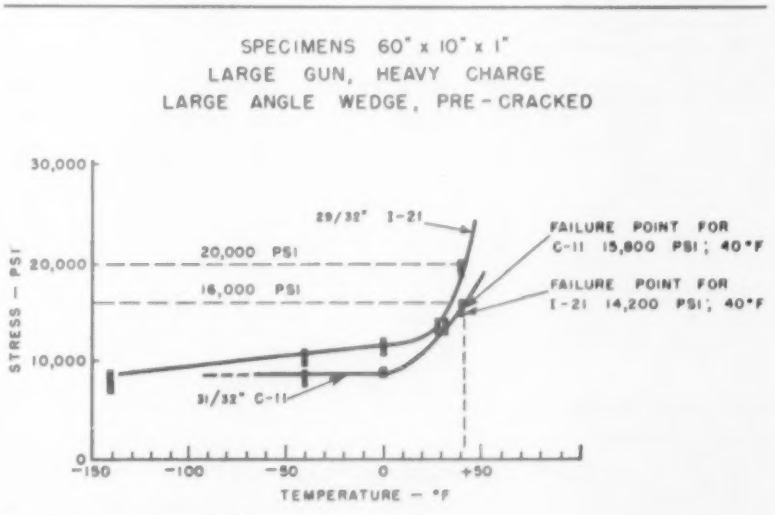


Fig. 5 Fawley tank steel

Effect of Plate Size

To extrapolate to the infinite plate, very large plates were tested at the University of Illinois, following some tests of intermediate size at Lehigh University. The largest specimens were 6 ft wide by 25 ft long by 1 in. thick. On these plates the jeweler's saw cut notch was employed with a small-angle wedge. The stress required to propagate the crack, at the same temperature as the impact energy series just described, was the same for this big plate as the stress to which the test results extrapolated for zero impact energy for the smaller plates. Therefore the same stress might be expected to be required for the infinite plate.

All of these test results, including the large plate work at the University of Illinois as well as the work with narrower plates with both the large and small wedge angles are presented graphically in Fig. 4. Curve *A* is for small plates with the large-angle wedge, precracked. Curve *B* is for the very large plates, and Curve *C* for smaller plates, both tested with the small-angle wedge,

Table 1 Properties of All Steels Tested

Steel plate specification →	A-1, ASTM A-285, Grade C	A-3, ASTM A-7	A-4, ASTM A-283, Grade C	A-5, ASTM A-7
Chemical properties				
Carbon	0.29	0.26	0.26	0.25
Manganese	0.40	0.84	0.46	0.55
Phosphorus	0.014	0.017	0.014	0.017
Sulfur	0.045	0.042	0.032	0.031
Silicon	0.04	0.03	0.06	0.02
Aluminum	0.0007	0.001	0.001	0.004–0.008
Aluminum oxide	0.0003	0.0005	0.0005	0.0005
Grain size, ASTM No.	8	9	8	8
Physical properties				
Yield point, psi	38,900	39,550	38,550	37,425
Ultimate strength, psi	67,700	67,500	62,950	65,800
Per cent elongation in 2 in.	32.5	36	37.5	36.3
Per cent reduction in area	54	58.6	58.8	57.3
Impact data Charpy V-notch →	*Temp, °F / Ft-lb*	*Temp, °F / Ft-lb*	*Temp, °F / Ft-lb*	*Temp, °F / Ft-lb*
	88 / 23, 23, 21	75 / 43, 45, 41	90 / 41, 40	80 / .....
	50 / 10, 13	60 / 28, 37	70 / 30, 35, 33	70 / 13, 16, 18, 19, 30
	40 / 9, 9, 12	50 / 17, 19, 19, 20, 25	60 / 16, 19, 23, 27	60 / 10, 11, 15, 19, 24
	30 / 8, 7	40 / 14, 14, 17, 20, 26	50 / 12, 13, 13, 14, 16, 18	50 / 8, 11, 12
	20 / 6, 6, 8	32 / 14, 22, 24, 16, 12	40 / 11, 11, 13, 9, 9, 10, 16	40 / 9, 9, 8
	10 / 4, 6	20 / 12, 12	32 / 11, 11, 9, 10, 9, 12, 9, 12	32 / 10, 6
	0 / 3, 3, 4	0 / 8, 8, 10	20 / 8, 7, 8	
	−20 / 3, 2	−10 / 7, 7, 7	0 / 4, 5, 5, 4, 6	
		−20 / 5, 5, 4	−20 / 3, 3, 3	
		−40 / 3, 3, 3		
Esso Brittle Temp at 18,000 psi, °F	50	50	50	70

Steel plate specification →	A-6, ASTM A-283 Grade C	A-7, ASTM A-283, Grade C	A-8, ASTM A-283, Grade C	A-9, ASTM A-283, Grade C
Chemical properties				
Carbon	0.24	0.15	0.15	0.15
Manganese	0.63	0.54	0.42	0.53
Phosphorus	0.023	0.008	0.019	0.014
Sulfur	0.040	0.012	0.031	0.016
Silicon	0.01	0.17	0.01	0.17
Aluminum	0.003	0.0005–0.015	0.04–0.007	0.001
Aluminum oxide	0.0008	0.0005	0.0005	0.0005
Grain size, ASTM No.	7	7	8	8
Physical properties				
Yield point, psi	39,750	35,250	37,300	35,775
Ultimate strength, psi	76,350	56,500	55,700	56,725
Per cent elongation in 2 in.	29	39	39.5	39
Per cent reduction in area	45.2	52.8	63.4	62.6
Impact data Charpy V-notch →	*Temp, °F / Ft-lb*	*Temp, °F / Ft-lb*	*Temp, °F / Ft-lb*	*Temp, °F / Ft-lb*
	90 / 22, 18, 14	+20 / 14, 10, 19	60 / 19, 19	32 / 25, 25, 28
	80 / 16, 15, 13	+32 / 22, 17, 25	50 / 13, 13, 13	20 / 15, 18, 20
	70 / 13, 10, 12, 13, 15	10 / 12, 9, 10	40 / 10, 11, 12, 13, 11	10 / 12, 12, 13, 14, 13, 16
	60 / 7, 10, 12, 13, 13	0 / 10, 11, 16	32 / 9, 9, 9, 9, 11	0 / 8, 11, 10, 10, 10
	50 / 6, 9, 10	−10 / 6, 7, 9	20 / 7, 7, 8	−10 / 7, 8, 11
	40 / 6, 5, 9	−20 / 3, 6	10 / 5, 6	−20 / 6, 7, 6
	30 / 8, 6, 8	−30 / 3, 3, 5		
Esso Brittle Temp at 18,000 psi, °F	60	−10	40	10

Steel plate specification →	A-10, ASTM A-283, Grade C	A-11, ASTM A-7	T-1, ASTM A-7	T-2, ASTM A-283, Grade C
Chemical properties				
Carbon	0.26	0.22	0.21	0.20
Manganese	0.59	0.73	0.59	0.49
Phosphorus	0.017	0.011	0.018	0.022
Sulfur	0.019	0.012	0.032	0.037
Silicon	0.01	0.02	0.02	0.22

Aluminum	0.001	0.001	0.001	0.0005
Aluminum oxide	0.0005	0.0006	0.0007	0.0003
Grain size, ASTM No.	8	9	9	8
Physical properties				
Yield point, psi	36,000	35,350	39,050	39,775
Ultimate strength, psi	69,000	63,450	62,150	62,450
Per cent elongation in 2 in.	35	39.8	38.5	37.8
Per cent reduction in area	54.4	64.3	64.3	62.0

Impact data Charpy V-notch →	*Temp, °F*	*Ft-lb*	*Temp, °F*	*Ft-lb*	*Temp, °F*	*Ft-lb*	*Temp, °F*	*Ft-lb*
	80	23, 26, 31	60	18, 22, 22	50	19, 20, 36	32	21, 33, 20
	70	16, 20, 23, 27, 36	50	14, 15, 15, 18, 19	40	16, 19, 21	20	20, 25, 30
	60	14, 19, 15, 15, 16	40	11, 16, 21, 15, 12	32	12, 13, 15, 21, 14	10	10, 11, 15
	50	13, 14, 19	32	8, 10, 9, 11, 12, 13, 14	20	9, 10, 11	0	8, 9, 10
	40	8, 7, 8					−10	5, 6, 6
	32	9, 8, 8						

Esso Brittle Temp at 18,000 psi, °F	70	50	40	10
Steel plate specification →	*T-3, ASTM A-283 Grade C*	*T-4, ASTM A-283, Grade C*	*T-5, ASTM A-283, Grade C*	*T-6, ASTM A-283, Grade C*
Chemical properties				
Carbon	0.23	0.24	0.18	0.23
Manganese	0.46	0.38	0.55	0.54
Phosphorus	0.021	0.021	0.021	0.015
Sulfur	0.036	0.050	0.024	0.026
Silicon	0.01	0.02	0.23	0.01
Aluminum	0.002	0.001	0.0005	0.002
Aluminum oxide	0.0005	0.0005	0.0003	0.0005
Grain size, ASTM No.	9	8	8	9
Physical properties				
Yield point, psi	45,500	42,875	43,600	33,550
Ultimate strength, psi	70,750	64,962	65,050	64,800
Per cent elongation in 2 in.	30.5	37.3	37.0	37.5
Per cent reduction in area	48.0	58.7	62.3	60.5

Impact data Charpy V-notch →	*Temp, °F*	*Ft-lb*	*Temp, °F*	*Ft-lb*	*Temp, °F*	*Ft-lb*	*Temp, °F*	*Ft-lb*
	50	7, 10, 11, 14, 15	50	8, 8, 10	10	25, 26, 27, 24	60	20, 23, 23
	40	7, 8, 8, 9, 12	40	6, 7, 8, 8	0	16, 18, 18	50	11, 14, 14, 15
	30	6, 7, 8	32	7, 8, 9	−10	13, 16, 17	40	10, 11, 11
	20	5, 6, 7	20	5, 6, 7	−20	10, 11, 13	32	7, 8, 8
			10	4, 6, 5			20	7, 9, 7
			0	5, 4, 4			10	6, 5, 5
			−10	4, 3, 4				

Esso Brittle Temp at 18,000 psi, °F	40	40	0	50
Steel plate specification →	*T-7, ASTM A-7*	*C-4, ABS,* Class C*	*C-5, ASTM A-284, Grade C*	*C-6, ASTM A-201, Grade B*
Chemical properties				
Carbon	0.17	0.19	0.25	0.18
Manganese	0.42	0.66	0.77	0.74
Phosphorus	0.018	0.015	0.015	0.020
Sulfur	0.052	0.035	0.042	0.033
Silicon	0.02	0.26	0.22	0.20
Aluminum	0.002	0.001		0.001–0.031
Aluminum oxide	0.0005	0.0003		0.0005
Grain size, ASTM No.	8	8	9	8
Physical properties				
Yield point, psi	45,000	44,625	40,500	34,500
Ultimate strength, psi	62,400	69,175	67,850	63,250
Per cent elongation in 2 in.	35.5	34.5	35.3	37.5
Per cent reduction in area	57.8	60.4	62.8	62.6

Impact data Charpy V-notch →	*Temp, °F*	*Ft-lb*	*Temp, °F*	*Ft-lb*	*Temp, °F*	*Ft-lb*	*Temp, °F*	*Ft-lb*
	40	18, 19, 19	72	48, 38, 46	90	65, 47, 53	20	19, 29, 32, 54, 53, 34
	30	16, 18, 19	50	27, 36, 37	60	45, 49, 52	10	13, 21, 29, 37, 56
	20	13, 13, 14	40	16, 27, 34	50	37, 43, 45	0	12, 12, 19, 34, 21, 50
	10	9, 10, 10	32	19, 24, 29, 30, 31	40	20, 14, 14, 30, 15, 30, 32, 24	−10	14, 8, 18, 9, 11, 24, 30, 31

	20 10, 12, 19	32 14, 15, 18, 30, 20, 32		
	0 19, 21, 7, 19, 26	20 9, 7, 10, 14, 12, 12		
	−20 10, 10, 12	10 8, 11, 12, 12		
	−40 8, 7, 4, 10			
	−50 4, 2, 2			
	−60 3, 4, 2			
Esso Brittle Temp at 18,000 psi, ° F	30	30	50	0

Steel plate specification ——→	*C-7, ABS,* Class C*	*C-8, ASTM A-201, Grade B*	*C-9, ASTM A-201, Grade B*	*E-1, P-403*
Chemical properties				
Carbon	0.17	0.17	0.17	0.15
Manganese	0.65	0.69	0.75	1.05
Phosphorus	0.020	0.017	0.015	0.015
Sulfur	0.019	0.016	0.026	0.049
Silicon	0.17	0.23	0.26	0.01
Aluminum	0.002–0.015	0.001	0.008	0.001
Aluminum oxide	0.0008	0.0005	0.008	Not detected
Grain size, ASTM No.	8	8	9	8
Physical properties				
Yield point, psi	36,975	39,400	40,400	34,300
Ultimate strength, psi	62,375	64,900	60,450	62,450
Per cent elongation in 2 in.	38.5	37.0	39.5	38
Per cent reduction in area	60.7	65.2	62.3	63.4

Impact data *Charpy V-notch* ——→	*Temp, ° F*	*Ft-lb*	*Temp, ° F*	*Ft-lb*	*Temp, ° F*	*Ft-lb*	*Temp, ° F*	*Ft-lb*
	50	59, 80, 84, 83	30	48, 51, 53	10	30, 33, 34	20	12, 16, 44
	40	57, 66, 69, 81	20	22, 41, 39, 40, 37, 41	0	19, 20, 23	10	10, 25, 42
	30	17, 18, 23, 52, 76	10	30, 30, 31, 45, 43 31	−10	12, 13, 16	0	10, 15, 22
	20	15, 29, 64	0	15, 15, 26, 36	−20	10, 11, 18	−10	8, 9, 25
	10	42, 32, 52, 12, 13						
	0	12, 26, 11						
Esso Brittle Temp at 18,000 psi, ° F		40		20		0		10

Steel plate specification ——→	*E-2, P-403*	*E-3, P-403*	*E-4, Coltuff*	*E-5, Coltuff*	*E-6, P-403*
Chemical properties					
Carbon	0.13	0.14	0.16	0.13	0.16
Manganese	1.19	1.41	1.08	1.00	0.87
Phosphorus	0.026	0.020	0.020	0.020	0.023
Sulfur	0.059	0.052	0.033	0.041	0.037
Silicon	0.04	0.01	0.15	0.14	0.01
Aluminum	0.004–0.012	Not detected	0.01	0.02	0.002–0.007
Aluminum oxide	0.0005	Not detected	0.001	0.001	0.0005
Grain size, ASTM No.	9	9	9	10	8
Physical properties					
Yield point, psi	44,000	46,150	44,175	44,650	32,450
Ultimate strength, psi	66,400	69,800	66,400	62,250	61,825
Per cent elongation in 2 in.	39.3	37.3	35.8	41.2	38.0
Per cent reduction in area	66.4	67.6	64.3	67.6	62.1

Impact data *Charpy V-notch* ——→	*Temp, ° F*	*Ft-lb*	*Temp, ° F*	*Ft-lb*	*Temp, ° F*	*Ft-lb*	*Temp, ° F*	*Ft-lb*	*Temp, ° F*	*Ft-lb*
	−10	30, 31, 32	10	39, 45, 50	30	17, 34, 43	−30	39, 52, 72	50	34, 43, 46
	−20	35, 36, 37	0	40, 48, 51	20	15, 30, 36	−40	31, 50, 64	40	19, 29, 52
	−30	9, 25, 28	−10	22, 23, 39	10	15, 21, 24	−50	11, 15, 16	30	14, 37, 57
	−40	21, 23, 25	−20	7, 20, 32	0	12, 15, 26	−60	7, 14, 34	20	10, 19, 41
Esso Brittle Temp at 18,000 psi, ° F		−20		0		20		−40		40

* American Bureau of Shipping.

notched with a jeweler's saw cut. All the data in this figure were obtained from specimens cut from the same plate, A-4 in Table 1. The powder charge and hence impact energy was the same for all three curves, 3500 ft-lb by actual ballistic test. This is enough, according to Curve *A* in Fig. 3, to lower the stress required with the sharp wedge and small plate, Curve *C* in Fig. 4.

Unfortunately, the stress level at which the crack can run even extrapolating to zero impact energy and the infinite plate, is too low to be a useful design stress. It seems to vary from plate to plate, averaging about 10,000 psi, as previously reported[3]. Furthermore, structures are not infinite and are subject to stress transients. One never knows what the actual stress in a structure is, especially locally where it may and probably usually does reach the yield stress. This is not important when behavior is ductile, but if the material be brittle these effects are important. Then, too, transient loadings may momentarily produce high stresses, which for even short durations are important when the material is brittle, because brittle cracks run at very high speeds and require very little energy to propagate. So designing for service below the brittle temperature

seems to be quite impractical. For this reason, attention was turned to behavior at temperatures for which the stress required for crack propagation would be adequately high.

In the tests of 6-ft-wide plates, brittle behavior occurred at the same stress as that to which the results on the smaller specimens extrapolated. It seems safe, therefore, to assume that 6-ft-wide plates are for all practical purposes infinite. Further, in tests carried out at 18,000 psi, the temperature below which brittle failure occurred but above which it did not agreed pretty well with the temperature determined by Robertson on this grade of steel, and with service experience in the case of the Fawley tanks.

This Fawley experience is related to laboratory test results in Fig. 5. Shown here is the original work with the Fawley tank steel, previously reported.[2] The large-scale test work in general gave a brittle temperature approximately 20° F higher than the original small-scale tests (Fig. 4). This would mean that the steeply rising part of the curves shown here should be moved approximately 20° to the right or to higher temperature. This size effect correction, which was indicated by the limited amount of size effect work previously reported,[2] brings the test results and the Fawley tank failures into good agreement.

Esso Brittle Temperature Test

In view of these considerations it was decided to use, for the purpose of evaluating a fairly large number of randomly selected heats, specimens small enough to be tested conveniently and relatively inexpensively, with a starting device that would result in the same brittle temperature at 18,000 psi as the large-scale test work. The specimen selected was 6 ft long and 16 in. wide by 1 in. thick. The weight of explosive in the cartridge of the rivet gun and the projectile weight were chosen so as to break the 16-in.-wide plates at the same temperature at 18,000 psi as was necessary in the 6-ft-wide plates. This work was done with plates A-4 and C-5, Table 1; for both plates the large and small specimen results were brought into agreement by the same change in powder charge and projectile weight. Eighteen thousand pounds per square inch was chosen for the stress at which to determine the brittle fracture because it is the nominal design stress in a tank, and also because it is sufficiently high to cross the curve in the transition temperature range where the curve has a steep slope. The lowest temperature at which the crack does *not* propagate completely across the plate (within approximately 10° F), as determined in this standardized testing procedure,

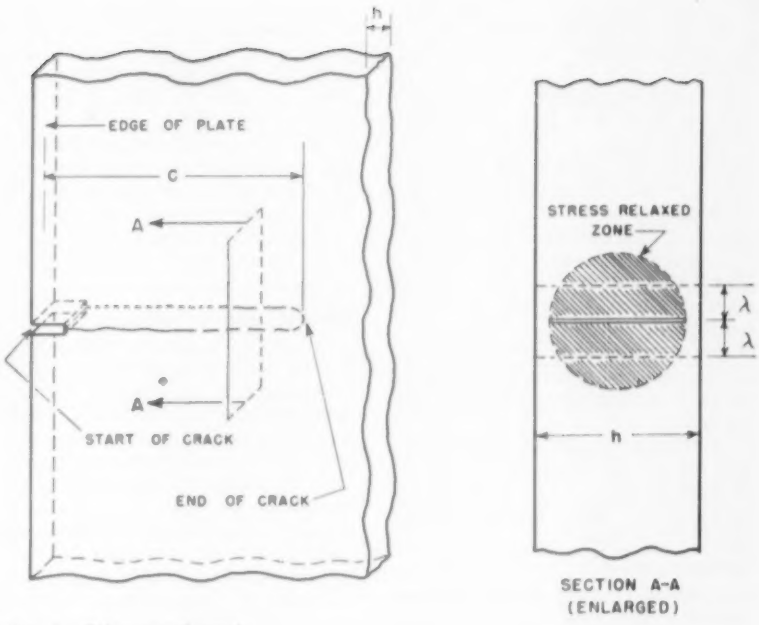


Fig. 6 Submerged crack

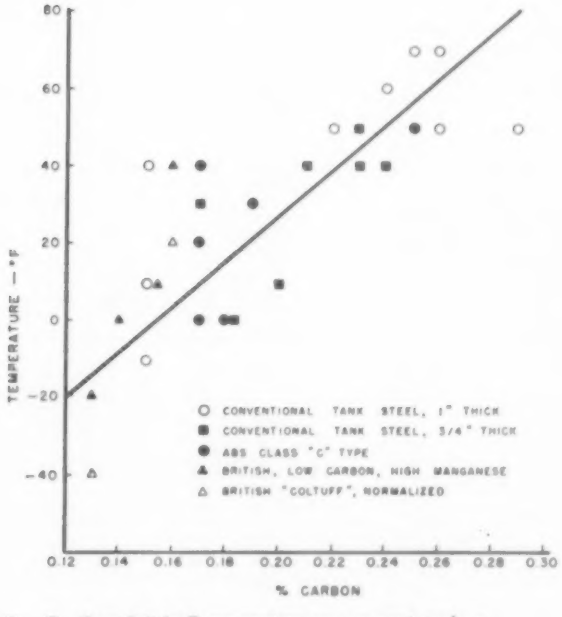


Fig. 7 Esso Brittle Temperature vs. percent carbon

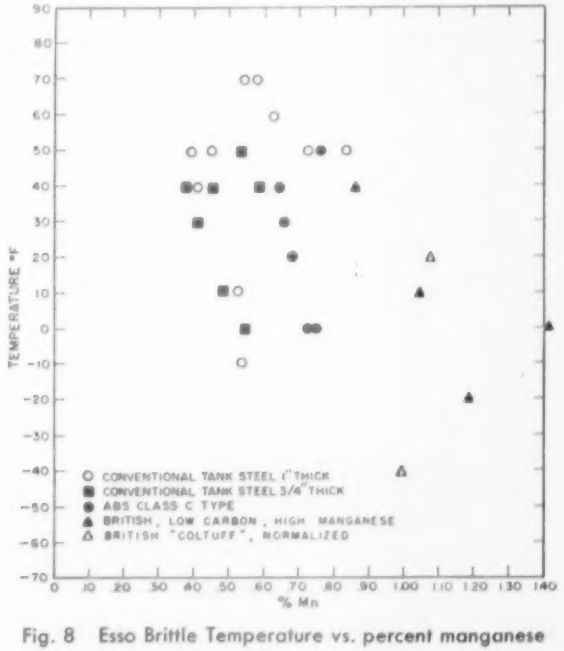


Fig. 8 Esso Brittle Temperature vs. percent manganese

for convenience and to differentiate it from other transition temperatures, will be referred to as the Esso Brittle Temperature.

It should be recognized that there is inherent in such a test as has been described many interrelated factors such as impact stress transients, stress redistribution during propagation and crack speed, about which little is known and which in themselves represent quite a formidable problem for research. This is particularly true when a small-scale specimen is tested at a low temperature where a very brittle crack of low energy requirement is produced. While employing such specimens several apparent anomalies were observed that are not as yet well explained. These phenomena are, briefly discussed below. The reader who is not much interested in these discussions may wish to skip directly to the section headed "Evaluation of Tank Steels."

Backing-up Effect

As described above it was possible to reproduce the large-plate brittle temperature with a small-scale specimen by lowering the impact. This same result was also obtained by backing up the small specimen with a 5000-lb weight and not changing the impact. However, when a back-up was employed with the small specimen below the brittle temperature, instead of raising the stress for fracture to bring it into agreement, it was decreased. It is thought that this different result in the effect of the back-up above and below the brittle temperature has its origin in a difference in the effect of the impact transient above and below the brittle temperature. At lower temperatures the wedge drives a longer crack than at higher temperatures. At higher temperatures there is an increase in the amount of shear lip. At higher temperatures repeated shots raise the stress required to break the plate, probably by reducing the stress concentration through plastic deformation. Just how these complex effects operate to lower the stress required to break the plate at low temperatures, but to raise it (or lower the required temperature at constant stress) at higher temperatures, is not completely clear to the authors.

Effect of Localized Cooling

A similar anomaly occurred while testing the large-scale plate. Here it was possible to lower the fracture stress 2000 psi when testing below the brittle temperature by subcooling with liquid nitrogen the local area around the saw cut. This effect could be caused to some extent by the unknown stress distribution due to this localized temperature gradient and also by its unknown effect on the energy transfer, speed of crack, etc. when the wedge is hit. Obviously under these conditions a 6-ft-wide plate cannot be considered the infinite plate it seems to be under uniform temperature testing.

Independence of Stress Requirement and Crack Size

The statement has been made that there may be a characteristic or critical stress, varying to some as yet undetermined degree from one steel to another and with thickness of plate and other variables, above which a crack will propagate and below which it will will not. It is asserted that by extrapolating to the infinite plate and to zero impact starting energy this value can be determined, for then the plate will be under a steady stress, free from transients except those inherent to the progress of the crack itself. Implicit in these statements is the assumption that the critical stress is independent of the length of the crack.

Now to have the critical stress independent of the length of the crack is incompatible with the generally accepted Griffith theory[6] of brittle strength, which was developed for glass and is almost certainly applicable to many materials. Why should steel, at temperatures somewhat below its brittle temperature, be an exception? The reason, it is here suggested, may lie not only in the necessity for plastic flow as a prelude to fracture, which leads to a limiting stress concentration and hence to a limiting value of the average stress, as pointed out by Gensamer in discussion of the previous report on this research,[2] but also to the necessity for modifying the Griffith crack theory to take into account a real difference between a running crack in a material as brittle as glass and a running crack in steel at a temperature not too far below the temperature at which the steel becomes ductile.

The Griffith Theory

The Griffith theory was developed for a crack that remains geometrically similar as it enlarges. Griffith derived his expression for the rate of energy release as a crack enlarges by taking Inglis'[7] exact solution for the stress around an elliptical tunnel perpendicular to the surface of an infinite plate under tension. While the expression he used is the expression for the energy released in the limit, as the ellipticity of the hole is increased, it nevertheless assumes a constant albeit very large ellipticity.

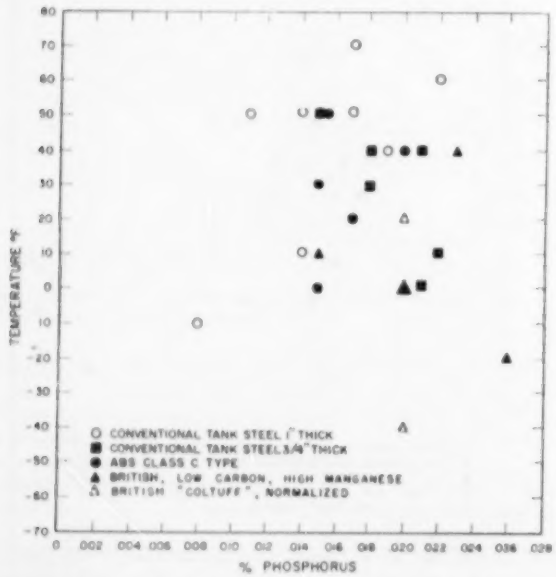


Fig. 9 Esso Brittle Temperature vs. percent phosphorus

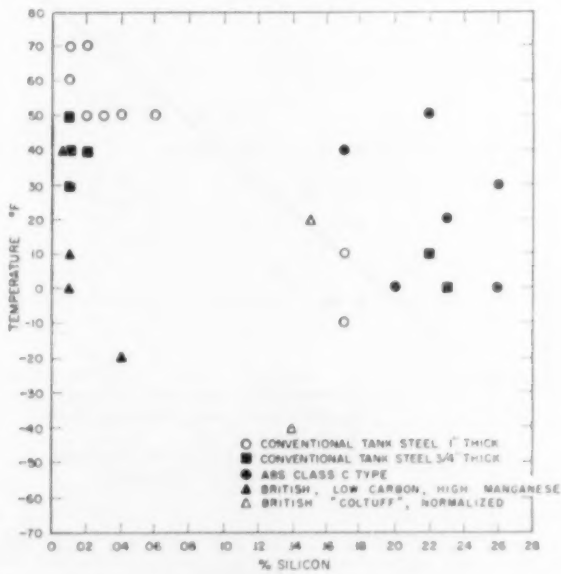


Fig. 10 Esso Brittle Temperature vs. percent silicon

As a result the energy made available, from the store of elastically stored energy, is proportional to the area of the elliptical hole, that is, to the square of its length or any other linear dimension. Griffith's expression using his symbols is

$$W = \frac{[3 - [(3-\sigma)/(1+\sigma)]]\ \pi c^2 R^2}{8\mu} \quad (1)$$

where W is the energy released, σ is Poisson's ratio, c is the semi-axis of the elliptical hole (half the length of a centrally located crack and without much error the whole length of a crack extending in from an edge), R is the tensile stress in the plate at a point remote from the crack, and μ is the modulus of rigidity or shear modulus. This is for unit thickness of plate.

When this is differentiated with respect to c, to get the rate of release of energy as the crack enlarges, one obtains the expression

$$dW/dc = \frac{[3 - [(3-\sigma)/(1+\sigma)]]\ \pi c R^2}{4\mu} \quad (2)$$

If the energy used is the area of the crack times the energy needed to make a unit area of crack, then for unit thickness of plate

$$U = 4cT \quad (3)$$

where U is the energy used and T is the energy required per unit of crack area. For glass Griffith used the surface tension for T, since glass is perfectly brittle and no work need be done except to overcome surface tension. Differentiating this

$$\frac{dU}{dc} = 4T \quad (4)$$

For the crack to continue running, it must receive energy at a greater rate than it is used. Hence the critical condition is

$$\frac{dW}{dc} = \frac{dU}{dc} \quad (5)$$

which results upon substitution of expressions (2) and (4) into (5) and making use of the relationship $\mu = E/[2(1+\sigma)]$, where E is Young's modulus, in the expression

$$R = \sqrt{\frac{2ET}{\pi\sigma c}} \quad (6)$$

which says that the stress required varies as the square root of the crack length. Irwin[8] and Orowan[9] have modified this expression, Irwin to make it applicable to a finite plate, and both to take into account the plastic deformation that accompanies progression of the crack near its surface, which generally is many times greater than the surface energy.

Nature of Long Cracks in Steel Plates

Observe that Griffith's expression derives from a situation where the total energy made available varies as the square of the crack length. This requires that the crack open up as it progresses, the opening being at all times proportional to its length. Now this is probably the situation in such a brittle material as glass, or for steel at very low temperatures, or for steel at higher temperatures when the crack is very small, say not many grain diameters in length. But there are many observations which support the point of view that this is not the situation for a long crack in steel at temperatures not too far below the transition or brittle temperature.

Cracks in service failures under circumstances where an extensive crack system develops have often been seen which seem to cross over other cracks; such could hardly be the case if the crack which is crossed over had opened up completely. Robertson has reported cracks which become submerged soon after starting, and then traverse the whole width of the test specimen (about a foot) without coming to the surface until near the opposite edge of the plate. Such long "submerged" cracks have been observed in the work reported in this paper. It is a commonplace that when a crack is stopped, it often extends several inches farther at mid-thickness than it does at the surface of the plate; this faster progress in the center relative to the surface, along with the origin of the characteristic fracture surface markings (chevron or herringbone) has been discussed by Boyd.[10] In the work reported herein, it was observed that short brittle cracks from "no-go" tests, when the cracked area was cut away from the rest of the plate, held together and required some force to separate, even though magnaflux inspection and subsequent visual examination showed complete cracking to have occurred.

As observed by Irwin,[8] Boyd[10] and others, cracks nucleate in advance of an approaching crack, and spread in all directions in the plane normal to the maximum tensile stress, including the direction opposite to that in which the crack as a whole is progressing. These nucleated cracks are not in exactly the same plane as the cracks which nucleate them, hence they overlap on meeting, leaving a thin bridge which will bend before breaking unless the metal is extremely brittle. There is also the well-known shear lip at the surface, which results from the crack losing its effectiveness as a stress raiser when its advancing edge gets near a free surface, with the onset of considerable plastic deformation before final fracture, now at the shear angle in this highly deformed zone rather than normal to the tensile direction. As in the ordinary tensile test, this shear lip will certainly develop just prior to fracture a resistance to deformation of the order of 100,000 psi, which at the high rate of deformation that must develop if the separation is to occur in thousandths of a second may be raised through the speed effect to perhaps double this, say 200,000 psi. (If the crack runs at 5000

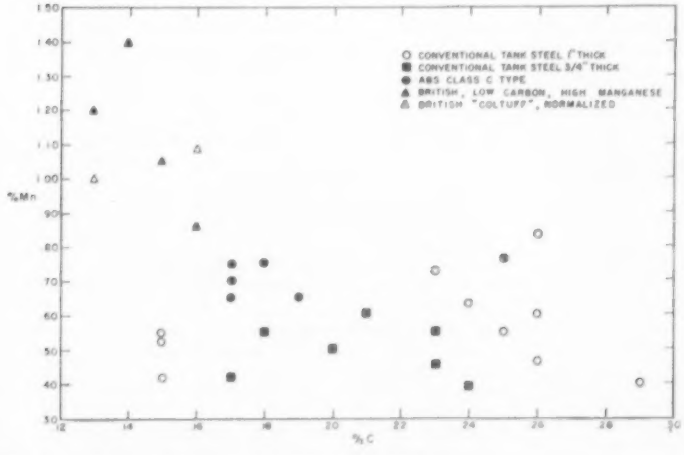


Fig. 11 Percent manganese vs. percent carbon

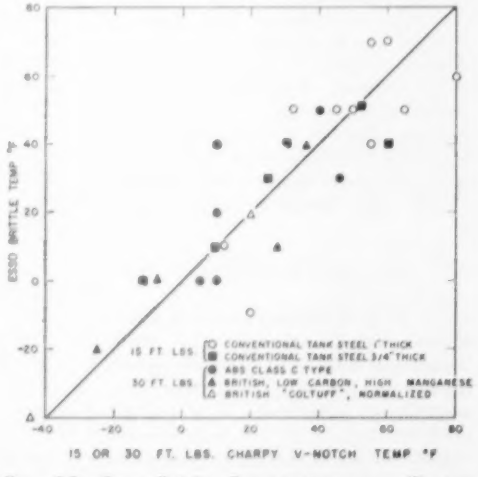

ESSO BRITTLE TEMP °F
15 FT. LBS.
30 FT. LBS.
CONVENTIONAL TANK STEEL 1" THICK
CONVENTIONAL TANK STEEL 3/4" THICK
ABS CLASS C TYPE
BRITISH, LOW CARBON, HIGH MANGANESE
BRITISH "COLTUFF", NORMALIZED
15 OR 30 FT. LBS. CHARPY V-NOTCH TEMP °F

Fig. 12 Esso Brittle Temperature vs. Charpy v-notch temperature

fps, it traverses 5 ft of plate in one millisecond; the plate need hold together along the surface and at isolated bridges for only this period of time, so high strain rates may develop.) For a 1-in. thick plate, requiring say 10,000 psi to crack it, a shear lip 0.025 in. wide on both surfaces (for a total of 0.050 in.) within which the stress reaches 200,000 psi would develop 10,000 psi averaged over the whole thickness of the plate, and prevent the crack opening up except in the immediate vicinity of the fracture surface.

In a large structure, such a very local and limited displacement will relax the stress to a very slight degree, and the elastic strain energy will be made available from only a small volume of material immediately adjacent to the crack, and extending an approximately equal distance away from it all along its length. It is as though a tunnel had been bored, now parallel to the direction of crack motion and not perpendicular to it and the plate as in the Griffith picture. Now the energy released and made available to do the work required for fracture varies linearly with the crack length (directly proportional to it) rather than as the square of the crack length as in the unmodified Griffith theory. This results in the stress required being constant, independent of crack length, rather than varying with the square root of the crack length as in the Griffith theory.

Modification of Griffith Theory

This may be formalized in the following way. Imagine the stress to be relaxed to zero in a volume the dimensions of which are c (the crack length for an edge crack), h (the thickness of the plate), and 2λ, where λ is the distance from the crack surface to which the stress may be taken to be completely relaxed. This is illustrated in Fig. 6. Of course, the stress builds up from zero gradually but in an unknown way with the distance from the free crack surface, so that the strain energy is reduced to its minimum value only at the free surface. The integrated energy released over the whole volume involved may be replaced by the product of the fictitious volume $2\lambda hc$ and the elastic strain energy originally stored in this volume, $S^2/2E$. Then the energy released would be

$$W = 2\lambda hc \frac{S^2}{2E} \qquad (7)$$

where W is the energy released, λ the distance from the crack surface to which the stress is considered to be completely relaxed, h is the plate thickness, c is the length of an edge crack, E is Young's modulus and S is the conventional engineering stress at points remote from the crack (R in Griffith's expression). Upon differentiating for the rate of energy release and setting the plate thickness h equal to unity this becomes

$$\frac{dW}{dc} = \frac{\lambda S^2}{E} \qquad (8)$$

which must be greater than the rate of energy consumption

$$\frac{dU}{dc} = 2\omega \qquad (9)$$

which differs from expression (4) in the use of ω which is the plastic energy requirement, rather than the surface energy T of Griffith's expression. The coefficient 2 replaces the 4 of expression (4) because it is for an edge crack and hence half as large. Equating (8) and (9) yields the expression

$$S = \sqrt{2\frac{E\omega}{\lambda}} \qquad (10)$$

which says that the stress required is independent of the crack length.

It may be that the crack does open up as the crack runs, but not linearly with it. This may be expressed by writing $\lambda = ac^n$ for which λ becomes equal to the constant a if n has the value of 0, and for which λ becomes linear with c as in the Griffith expression when $n = 1$. For intermediate values of n, representing real cases, λ increases rapidly at first while the crack is small but more slowly as the crack lengthens. It seems probable that n in real cases has a low value, much nearer zero than unity. Our expression for W then becomes, for unit width

$$W = ac^{(n+1)}\frac{S^2}{E} \qquad (11)$$

which differentiates to

$$\frac{dW}{dc} = (n+1)ac^n\frac{S^2}{E} \qquad (12)$$

which upon equating to the rate of energy consumption yields

$$S = \sqrt{2\frac{E\omega}{(n+1)ac^n}} \qquad (13)$$

Now the stress varies inversely with the crack length raised to the $n/2$ power. $c^{n/2}$ is not far from unity when n is small, and this would result in only a slight variation of stress with crack length. This last expression then reduces, as before, to

$$S = \sqrt{2\frac{E\omega}{\lambda}} \qquad (10)$$

Should further work establish the reality of a limit stress, below which at a given temperature a crack will not run, it may be possible to reconcile its value by the use of either of two limiting conditions; the first based on a stress concentration limited by plastic deformation and a critical stress required for this plastic deformation,[2] and the second based on the Griffith theory modified to take into account the limited extent to which a rapidly moving crack opens up and releases energy as it progresses. It might be noted in passing that λ should be related to the thickness of the plate h, perhaps linearly, in which event the stress would vary with thickness according to equation (10), with h replacing λ. Then the brittle breaking strength would be expected to diminish as the plate thickness increases, and this would lead to an increase in the brittle temperature as the plate thickness increases.

Evaluation of Tank Steels

Recognizing that there is always a possibility of crack initiation in a tank (always attempting to reduce the probability by careful welding, inspection, etc.) the engineer is forced to find for each installation a steel of adequate resistance to crack propagation, taking into account the minimum service temperature and the consequences of failure in each instance. This tank steel should not propagate a brittle crack at the lowest service temperature and highest design stress that it will see in service. This stress is currently 17,850 psi, based on a design stress of 21,000 psi to which a joint efficiency of 85% is applied; this is taken in this paper to be 18,000 psi. The standardized test just described was employed to determine the Esso Brittle Temperature for several types of steel. The steels tested fall into five broad categories.

Given in Table 1 is a summary of the chemical, physical and Charpy impact properties as well as grain sizes and the Esso Brittle Temperature for all the

Symbol	*Nominal plate thickness, in.*	*Type of steel*	*No. of steels tested*
A	1	Conventional semikilled or rimmed tank steel (ASTM A-7, A-283 grade C, and A-285 grade C)	10
T	3/4	Conventional semikilled or rimmed tank steel (ASTM A-7, A-283 grade C, and A-285 grade C)	7
C	1	Fully killed steel, fine-grain practice (ABS class C ship steel; ASTM A-201 grade B and A-284 grade C)	6
E	1	British low carbon, high manganese steel (semikilled)	4
E'	1	Normalized low carbon, high manganese steel ("Coltuff")	2

steels tested. From these data it is possible to make the following brittle temperature comparison, for plates of the same thickness.

Symbol	Type of steel	Esso Brittle Temp., ° F Low	High	Avg
A	Conventional semikilled or rimmed	−10	+70	+44
C	Fully killed (fine-grain practice)	0	+50	+24
E	British low carbon, high manganese	−20	+40	+ 8
E′	Low carbon, high manganese, normalized	−40	+20	−10

Clearly there was considerable spread in the results, but there is a definite indication that the British low carbon, high manganese, semikilled steel was superior to either conventional tank steel or fully killed, fine-grain practice steel; the latter is also somewhat better than conventional tank steel. It will be shown later in this paper that this ranking can probably be correlated with the carbon content of the steel rather than differences in steel-making practice or alloy content. If one were to take the most conservative approach and consider only the worst plate of each type tested, the spread in quality is not great.

Effect of Plate Thickness

It is well known that the transition temperature measured in any way is higher the thicker the plate. Tests were made limiting the thickness comparison to steels of one type, namely, conventional tank steel, ASTM A-7, or A-283 grade C. The results of this comparison are summarized below.

Symbol	Thickness, in.	No. of plates tested	Esso Brittle Temp, ° F Low	High	Avg
T	3/4	7	0	+50	+30
A	1	10	−10	+70	+44

From this table it can be seen that while the 1-in. plate results completely surround the 3/4 in. plate results, 3/4-in. thick plate is, on the average, about 15° F better than 1-in. thick plate.

Effect of Chemical Composition

An attempt has been made to relate the Esso Brittle Temperature to other properties of these steels. It looks as though there is a relationship between carbon content and brittle temperature. This is shown in Fig. 7 for all of the 29 steels tested. The data show a trend indicating that low carbon steels are better than higher carbon steels. Several of the seeming discrepancies, such as the extremely low Esso Brittle Temperature for two of the 1-in. A-7 plates and the high brittle temperature for one of the fully killed steel plates, can be explained on this basis. There are still, of course, wide variations in results, but this should be expected when one considers the widely varying steel-making practices, chemical compositions and rolling conditions covered by the group of steels tested.

clue to variations in "deoxidation practice" is the aluminum content, especially the aluminum not fixed as alumina, or as aluminum nitride. Several plates, for which the points in Fig. 7 lay farthest from the line, were analyzed* for soluble aluminum, insoluble aluminum and nitrogen combined as aluminum nitride, with the results summarized in the following tabulation:

Plate No.	Esso Brittle Temp, ° F	Carbon	Manganese	Soluble aluminum	Insoluble aluminum	Aluminum nitride nitrogen	"Ferrite" grain size
A-5	70	0.25	0.55	0.008	0.001	0.0002	8
A-8	40	0.15	0.42	0.007	0.001	0.0002	8
A-7	−10	0.15	0.54	0.015	0.001	0.0002	7
C-7	40	0.17	0.65	0.015	0.001	0.0004	8
C-6	0	0.18	0.74	0.031	0.002	0.0009	8
E-6	40	0.16	0.87	0.007	0.001	0.0002	8
E-2	−20	0.13	1.19	0.012	0.001	0.0002	9

Figures 8, 9 and 10 show the relation of manganese, phosphorus and silicon with the Esso Brittle Temperature. There seems to be some evidence of a correlation with manganese, but this depends largely on the British steels, which also comprise most of the low-carbon group, as shown in Fig. 11. It may therefore be that the apparent correlation with manganese is largely fortuitous, resulting from the systematic variation of manganese with carbon. There would then necessarily be a correlation with the manganese-carbon ratio.

The same conclusions can be drawn from the National Bureau of Standards work reported by Williams[11] and the Naval Research Laboratory work reported by Pellini and his associates.[12, 13, 14] Here again the correlation of transition temperature is more convincing for carbon than for manganese, and the manganese correlation could be derived from a systematic variation of manganese with carbon, which may be seen in Williams' Fig. 10, and may be derived from Pellini *et al.* by plotting their data for drop-weight temperature against composition. In the Naval Research Laboratory data comparison should be restricted to as-rolled plates, eliminating the normalized plates. It should be noted that in both these studies the manganese contents of as-rolled plates were all low, which may make them inapplicable to higher manganese steels.

There is obviously considerable scatter of the points in Fig. 7, which of course could be accounted for if one knew all the variables entering into the fixing of the brittle temperature. The complex of variables associated with the "deoxidation practice" may be as important as the composition variables just discussed, perhaps even as important as the carbon content. One

The seven plates analyzed are grouped into three manganese levels, all in the low-carbon range except the first one listed, plate A-5. There seems to be little correlation with manganese, except possibly for plate E-2 with the highest manganese; but here the carbon is lowest. Note that in the first, or low manganese group, the highest brittle temperature is associated with high carbon and low aluminum, the intermediate brittle temperature is associated with low carbon at the same aluminum level, and the lowest brittle temperature is associated with low carbon and high aluminum. In the second, or intermediate manganese pair, both plates have nearly the same carbon, and the low brittle temperature is associated with high aluminum. In the third, or high manganese pair, the low brittle temperature is again associated with high aluminum; here the carbon is lower and manganese is higher, but by amounts less than would be expected to produce the large difference in brittle temperature. Observe that all seven steels are fine grained in the as-rolled condition. These specific comparisons support the tentative conclusions that manganese has no large specific effect, that carbon has a rather pronounced effect, and that "deoxidation practice" may have an effect as great as that of carbon in determining the brittle temperature.

Correlation with Charpy Impact Values

In Reference 3, a correlation was shown between the SOD transition temperature (the temperature where the plateau section of the curve ends and stress starts rising rapidly) and the temperatures at which Charpy V-notch

* The chemical analyses were kindly made by the analytical laboratory of the Applied Research Laboratory of the United States Steel Corp. at Monroeville, Pa. The analytical values tabulated are weight per cent.

impact values are 4 to 6 ft-lb. This correlation is modified herein because of two factors:

1. The test has been modified to use a 15° wedge with reduced impact in order to give results similar to plates 72 in. wide. The results thus obtained are slightly different from earlier results.

2. The criterion for evaluating steels has been changed to the temperature at which a brittle crack stops at 18,000 psi (the Esso Brittle Temperature).

Table 2 shows the correlation between impact values and the Esso Brittle Temperature. In this table, the Esso Brittle Temperature is shown along with the mean Charpy V-notch impact value obtained at the Esso Brittle Temperature. This mean was arrived at by visual inspection of a plot of impact values versus temperature; the limited number and the scatter of the individual points listed in Table 2 did not justify the use of a more elaborate method. The mean was chosen rather than the minimum observed Charpy value primarily because statistically a more satisfactory value with a relatively small number of specimens can be obtained for a mean than for an extreme. In Reference 4, it was pointed out that there was no clear correlation, referring to minimum values. The correlation with the observed mean, used in this paper, is much better; it is shown in Fig. 12.

The results in Table 2 indicate that for conventional semikilled and rimmed tank steels, 15 ft-lb is the approximate mean value of the Charpy V-notch impact energy corresponding to the Esso Brittle Temperature. For fully killed (fine-grain practice) and low carbon, high manganese steels the approximate mean impact energy at the Esso Brittle Temperature is about 30 ft-lb. In arriving at these figures, occasional high values caused by fissuring in the fracture surface were ignored; fissuring, attributable to nonmetallics, always results in anomalously high Charpy impact values.

Pellini and associates[13] at the Naval Research Laboratory called attention to the need for using a different energy level for as-rolled conventional plate steels and for normalized low carbon, high manganese steels, 15 ft-lb in the former corresponding to about 50 ft-lb in the latter (see Pellini's Fig. 11), both at the fracture transition temperature in the explosive bulge test. Note that in that work the low carbon, high manganese steels were normalized, whereas in the work reported here the steels were not normalized. This may account for the correlation with about 30 ft-lb rather than the 50 ft-lb in the Naval Research Laboratory work. Figure 11 shows the relationship between the Esso Brittle Temperature and either the 15 ft-lb or the 30 ft-lb V-notch Charpy temperature, whichever is appropriate.

The authors wish to emphasize that the temperature aspect of this correlation is much more important than the energy level that is chosen, primarily because the ductility of notched bars of steel changes quite rapidly with temperature, even in V-notch Charpy testing. Changing the test temperature in the transition range even as little as 10° F changes the mean Charpy energy value by quite a number of foot-pounds. Consequently, whether 15 or 30 ft-lb is chosen as the energy level at which to make the temperature comparison is not of great importance, provided both energy levels lie within the transition range, as they do for the grades of steel under consideration here.

Recommendations

The authors believe that, if it were possible to purchase conventional tank steel on a quantity basis with impact requirements, a specification of 15 ft-lb average Charpy V-notch at the minimum operating temperature would give good assurance against tank failures. With steels made to fine-grain practice, and possibly also semikilled steels of the low carbon, high manganese variety, 30 ft-lb V-notch Charpy would give this assurance. In both instances the Charpy fracture surface should show no fissuring.

Table 2—Correlation Esso Test Results with Charpy V-Notch

Type of steel	*Plate No.*	*Esso Brittle Temp*	*Temp corresponding to 15 ft-lb Charpy V, ° F*	*Temp corresponding to 30 ft-lb Charpy V, ° F*	*Estimated mean Charpy energy at Esso Brittle Temp*	*Avg.*
Conventional tank steel						
1 in. thick	A-1	50	65	...	11	
	A-3	50	30	...	22	
	A-4	50	50	...	16	
	A-5	70	60	...	16	
	A-6	60	80	...	10	
	A-7	−10	20	...	8	
	A-8	40	55	...	11	
	A-9	10	10	...	13	
	A-10	70	55	...	23	
	A-11	50	45	...	17	14.7
3/4 in. thick	T-1	40	30	...	19	
	T-2	10	10	...	14	
	T-3	40	60	...	9	
	T-4	40	80	...	8	
	T-5	0	−10	...	20	
	T-6	50	50	...	15	
	T-7	30	25	...	16	14.4
Fully killed, fine-grain practice	C-4	30	...	45	23	
	C-5	50	...	40	37	
	C-6	0	...	5	27	
	C-7	40	...	10	65	
	C-8	20	...	10	39	
	C-9	0	...	10	22	29.6*
British low carbon, high manganese, as-rolled	E-1	10	...	30	22	
	E-2	−20	...	−25	32	
	E-3	0	...	−10	37	
	E-6	40	...	+35	35	31.5
British "Coltuf," normalized	E-4	20	...	+20	27	
	E-5	−40	...	−45	40	33.5

* Excluding plate number C-7 because of fissures in the fracture surface.

Unfortunately, a high percentage of the steel rolled would not be applicable in locations where atmospheric temperatures fall befow 50° F. Since purchase of steel on a quantity basis to such requirements has not been practical in the past, it appears that the best basis for future tank steel specifications, for application in localities where severe winters are experienced, would be to limit carbon content to as low a value as is practical, permitting increased manganese to maintain the required tensile strength, and requiring the steel maker to control the other variables that affect the brittle temperature. A 0.12% carbon limit would be satisfactory for 1-in. thick plates in most northern locations; thinner plates could tolerate more carbon, thicker less. It is planned to test trial heats of steels of this type manufactured in the United States to see if the results are in line with those of the British low carbon, high manganese steels reported in this paper.

Acknowledgments

The authors wish to thank the Esso Research and Engineering Co. for its encouragement in performing these experiments and publishing the results, and to acknowledge the assistance of various of their colleagues who at one time or another have been associated with the work. J. S. Clarke helped plan the work in its early stages and participated at various times throughout. H. C. North spent nearly full time for several months, D. Hrtko succeeded him and was in turn succeeded by W. M. Cooper who remained with the experimental program until its completion. R. A. Haisch and S. F. Herbster provided enthusiastic and invaluable laboratory assistance.

References

1. Feely, F. J., Jr., and Northup, M. S., "Why Storage Tanks Fail," *Oil and Gas Jnl.*, 73–77 (February 1954).

2. Feely, F. J., Jr., Hrtko, D., Kleppe, S. R., and Northup, M. S., "Report on Brittle Fracture Studies," THE WELDING JOURNAL, **19** (2), *Research Suppl.*, 99-s to 111-s (1954).

3. Feely, F. J., Jr., and Northup, M. S., "Study of Brittle Failure in Tank Steels," Preprint, 19th Mid-Year Meeting, A.P.I., Div. of Refining, Houston, Tex. (May 11, 1954).

4. Feely, F. J., Jr., and Northup, M. S., "Properties of Steel for Tank Construction," *Proceedings*, Fourth World Petroleum Congress, Rome, Italy. Section VII, paper B-3 (June 6–15, 1955).

5. Robertson, T. S., "Propagation of Brittle Fracture in Steel," *Jnl. Iron Steel Inst.*, **175**, 361–374 (December 1953).

6. Griffith, A. A., "The Phenomena of Rupture and Flow in Solids," *Phil. Trans., Roy. Soc. London*, **A221**, 163–198 (1921).

7. Inglis, C. E., "Stresses in a Plate Due to the Presence of Cracks and Sharp Corners," *Trans. Inst. Naval Arch.*, **LV**, Part 1, 219–230 (1913).

8. Irwin, G. R., "Fracturing and Fracture Dynamics," *Trans., Am. Soc. Metals*, **40A**, 147 (1948). (See also Irwin, G. R., and Kies, J. A., THE WELDING JOURNAL, **17** (2), Research Suppl., 95-s to 100-s (1952).

9. Orowan, E., "Fundamentals of Fatigue and Fracture of Metals" (MIT Symposium), John Wiley and Sons, New York (1952), pp. 154–155.

10. Boyd, G. M., "The Propagation of Fractures in Mild-Steel Plates," *Engineering*, 65–69 Vol. No. 175 (Jan. 16, 1953).

11. Williams, M. L., "Analysis of Brittle Behavior in Ship Plates," Special Technical Publication, No. 158, ASTM.

12. Puzak, P. P., Eschbacher, E. W., and Pellini, W. S., "Initiation and Propagation of Brittle Fracture in Structural Steels," THE WELDING JOURNAL, **17** (12), Research Suppl., 561-s to 581-s (1952).

13. Puzak, P. P., Schuster, M. E., and Pellini, W. S., "Applicability of Charpy Test Data," *Ibid.*, **19** (9), Research Suppl., 433-s to 441-s (1954).

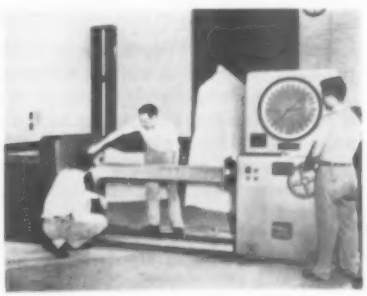
14. Puzak, P. P., Schuster, M. E., and Pellini, W. S., "Crack-Starter Tests of Ship Fracture and Project Steels," *Ibid.*, **19** (10), Research Suppl., 481-s to 495-s (1954).

RESEARCH NEWS

New-Principle Torsion Testing Machine Installed

One of the first torsion-testing machines in which torsion measurements are made electrically by means of an SR-4 resistance wire strain gage device has been installed in the University of Virginia's Materials Testing Laboratory, Charlottesville, Va.

The new machine is of 60,000 in.-lb capacity and will be used by undergraduate engineering students in studying torsional strength of solid and hollow shafts, structural shapes and certain aircraft structures. It is anticipated that it will be used experimentally in the study of stress analysis in a graduate course. The machine will also be available for research projects of the University of Virginia Engineering Experiment Station.



The machine accommodates test specimens having a maximum length of 6 ft between chucks. It has a reversible drive with an infinitely variable speed range of 5 to 200 deg per minute. Both the machine and its SR-4 torque pickup were developed by Baldwin-Lima-Hamilton Corp. The torque pickup is essentially a low deflection steel shaft on which SR-4 resistance wire strain gages are bonded in such manner as to cancel bending and thrust strains. It has no moving parts.

Output of the torque pickup is fed by a single cable into an electronic amplifier and indicating instrument which provides three ranges on a 24-in. diam dial that reads directly in inch-pounds for twists in both directions. Lowest range is 0–6000 in.-lb. Response to load changes is fast: up to full dial in 1 sec. Faster response is obtainable with oscillograph or oscilloscope. A load-torque recorder can be used with the machine also.

Lehigh Dedicates New Building

Lehigh University dedicated its new Fritz Engineering Laboratory and the world's largest universal testing machine on October 14th, according to an announcement by Dr. Martin D. Whitaker, president of the university. The new building, completed after three years of construction, also will house a dynamic testing bed featuring Amsler equipment unique in this country.

The new building consists of a seven-story section 130 by 70 ft and a four-story section 114 by 24 ft. The main test bay of the new building measures

(*Continued on page 624-s*)

STRESSES FROM RADIAL LOADS AND EXTERNAL MOMENTS IN CYLINDRICAL PRESSURE VESSELS

Design information on deflections, bending moments and membrane forces, and on the influence of internal pressure

P. P. BIJLAARD

ABSTRACT—This paper is sequential to that published in the December 1954 issue of THE WELDING JOURNAL.[1] It contains design information on the rotations, bending moments and membrane forces caused in cylindrical vessels by circumferential and longitudinal moments transmitted through various attachments. Moreover, it contains data for finding the reducing influence of internal pressure on the deflections, rotations, bending moments and membrane forces caused by radial loading as well as by circumferential and longitudinal moments. The cylindrical shell is assumed to be held round (simply supported) at the ends. Comparison with the well known tests by Schoessow and Kooistra shows good agreement between computed and experimental values. The published results were obtained as part of a research project on Effects of External Loads on Pressure Vessels sponsored at Cornell University by the Pressure Vessel Research Committee of the Welding Research Council.

Points Where Angle Rotations, Bending Moments, and Membrane Forces from External Moments Were Determined

Both circumferential (Fig. 1) and longitudinal moments (Fig. 2) were considered. These external moments from various attachments (pipes, lugs, clips, etc.) are assumed to be transmitted to the shell by distributed radial loads which, within the rectangular area of the attachment, are constant in the direction of the moment axis and vary linearly in the direction perpendicularly to it (Figs. 1 and 2). The angle rotation θ of an attachment from a circumferential moment was computed as the deflection of the point Q_1 divided by the distance c_1. The location of Q_1 is clear from Figs. 1*a*, *b*, *c* and *d*. Of course, the deflection of point Q_2 is equal but opposite to that of Q_1. The bending moments M_ϕ (circumferential) and M_x (longitudinal) and the membrane forces N_ϕ and N_x were calculated for the point Q_1, which is the point outside the attachment where the stresses are assumed to be generally highest. Again, in Q_2 the stresses are equal and opposite to those in Q_1.

In a similar way the angle rotation from a longitudinal moment is the quotient of the deflection in R_1 and the distance c_2 (Fig. 2). The bending moments and membrane forces for this loading were computed for the point R_1.

For nonrectangular attachments the loaded rectangle can be assumed to be that which has the same moment of inertia, with respect to the moment axis, as the plan of the actual attachment. Further it should be assumed that the dimensions of the rectangle in the longitudinal and circumferential directions have the same ratio as the two dimensions of the attachment in these directions. This is explained further in the section on the comparison of the theory with test results.

Signs of Bending Moments and Membrane Forces

Although this may be unnecessary for many readers, since it follows directly from considerations of equilibrium, attention is called to the fact that in the region of an external radial compressive loading P, positive bending moments M_ϕ and M_x arise, that is, moments that cause compressive stresses at the outside of the shell. These same loads P create negative membrane forces in the loaded region, that is, compressive ones. Inversely, external radial tensile loading or internal radial compressive loading causes negative moments and positive membrane forces.

This also follows from Tables 1 and 2 of reference 1, where P is an external radial compressive load and where M_ϕ and M_x are positive and N_ϕ and N_x are negative. In Figs. 7 and 8 of reference 1, where the absolute values of N_ϕ and N_x are plotted, N_ϕ and N_x are compressive forces for a compressive external load P and tensile forces for tensile external loads P or compressive internal loads P.

Hence, due to the adjacent compressive external loading, in the present Figs. 1 and 2 in the points Q_1 and R_1, respectively, the bending moments M_ϕ and M_x are positive and the membrane forces N_ϕ and N_x are negative. In the points Q_2 and R_2 of Figs. 1 and 2, respectively, the bending moments are negative and the membrane forces are positive. The graphs in Figs. 4–6 and 8–10 give the absolute values of the bending moments and membrane forces.

Effect of External Circumferential Moments

Numerical data for the angle rotations θ, the bending moments M_ϕ and M_x and the membrane forces N_ϕ and N_x were computed from the author's equations[2] by the use of IBM machines. The results for point Q_1 in Fig. 1 are given in Tables 1 and 2. The bending moments and membrane forces are given per unit width of shell wall. M is the external circumferential moment, and

$$\alpha = l/a,\ \gamma = a/t,\ \beta_1 = c_1/a \text{ and } \beta_2 = c_2/a$$

where l, a and t, as shown in Fig. 1, are the length, the radius and the thickness of the vessel, respectively. The dimensions of the loading surfaces are $2c_1 \times 2c_2$ where c_1 and c_2 are measured in the circumferential and longitudinal directions, respectively. E is the elastic modulus.

Figs. 3, 4, 5 and 6 present graphs for the angle rotations, the bending moments and the membrane forces from

P. P. Bijlaard is Professor of Structural Engineering, Cornell University, Ithaca, N. Y.

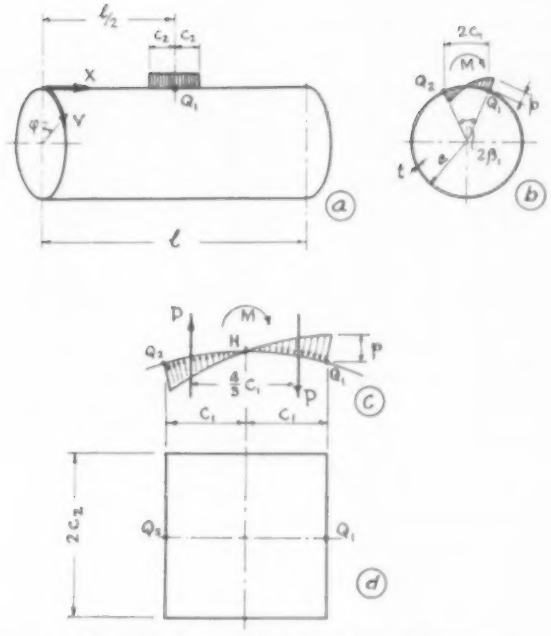


Fig. 1 Loading of vessel by circumferential moment

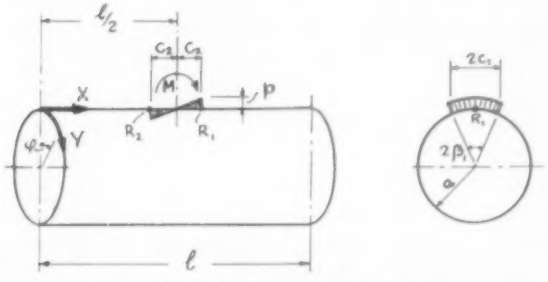


Fig. 2 Loading of vessel by longitudinal moment

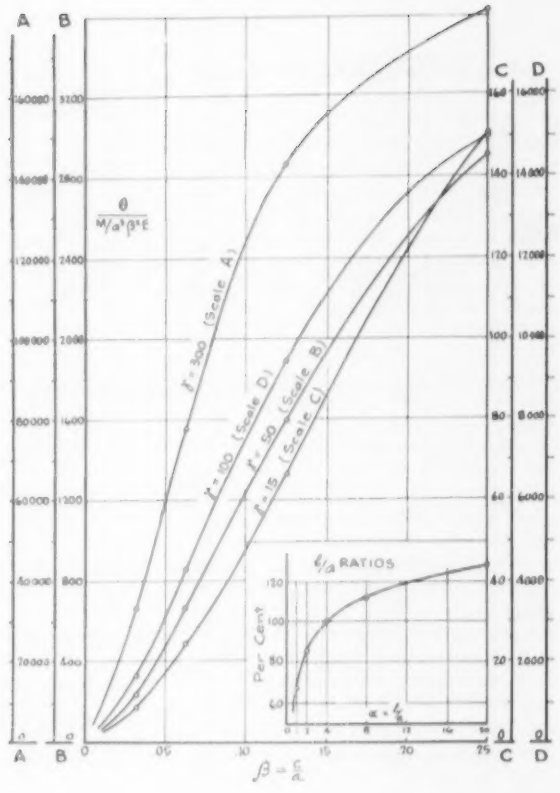


Fig. 3 θ vs. β Angle rotation from external circumferential moment M on surface $2c \times 2c$ on a cylindrical shell with radius a ($\gamma = a/t$)

loadings on *square* loading surfaces ($\beta_1 = \beta_2 = \beta$). They are based on the data of Table 1, which are indicated by circles. These data refer to a ratio $\alpha = l/a = 4$. But from the first five cases of Table 2 for l/a larger than one it is seen that the bending moments and membrane forces are practically independent of the ratio l/a, so that Figs. 4, 5 and 6 apply to any ratio $\alpha = l/a$ not smaller than 1. Only the angle rotations vary with the ratios l/a and in Fig. 3 an auxiliary graph is given to take this into account. After having found from Fig. 3 the angle rotations for $\alpha = 4$, this auxiliary graph in Fig. 3 gives the percentage of these values that has to be used for ratios other than 4. The other results in Table 2 refer to rectangular loading areas. A method to reduce these to equivalent square loading surfaces is given below.

In Fig. 3 the angle rotation θ is shown in terms of $M/(a^2\beta^2E)$. This was done in order to be sure how to extrapolate the graphs to the left. The ordinates of the curves now are proportional to the deflection of the point Q_1 from unit loads $P = M/(^4/_3c_1)$ (Fig. 1*c*). Under this loading the shell acts as if it were hinged along a generatrix through H (Figs. 1*c* and 11). For small ratios $\beta = \beta_1 = c_1/a$ the ordinates increase almost parabolically with increasing β, because for the same load P, the external moment, and thus the angle rotation θ, increase with β, while the deflection of the point Q_1 is again $a\beta$ times this angle rotation. For higher ratios β the curves flatten out due to the greater influence of the larger area over which the load P is distributed.

Figure 4 gives M_ϕ and M_x in terms of $M/(a\beta)$, so that the ordinates of the curves are proportional to M_ϕ and M_x from the above unit loads P (Figs. 1*c* and 11). For small β values the curves for M_ϕ approximate a value of about $0.11\ M/(a\beta)$, independent of $\gamma = a/t$. This may be verified in a simple way. For small loading surfaces (small β) the shell acts practically as a plate, that is, without the benefit of the load carrying capacity of the membrane stresses. If $c = \beta a$ is very small, from Fig. 11*a* the reaction in the hinged edge H will approximate the value of P, so that from Fig. 11*b* the cross section KK will have to resist a total moment of $^2/_3\ cP$. As shown in Fig. 11*b* the effective width of KK can be approximately assumed as $4c$, so that $M_\phi = {}^2/_3\ cP/(4c) = {}^1/_6\ P$. With $P = M/(^4/_3c)$ (Fig. 1*c*) this becomes $M_\phi = 0.125\ M/c = 0.125\ M/(a\beta)$ which is of the same order of magnitude as $0.11\ M/(a\beta)$ from Fig. 4.

Both M_x and M_ϕ are the larger, the smaller $\gamma = a/t$, that is, the thicker the shell. This is so because in the thick shells, due to the larger bending rigidity of the shell wall, the loads P are distributed over a larger area (plate action) than in the thin shells. This, of course, causes larger moments in thick than in thin shells. The load distributed by the flexural rigidity of the shell is carried by the membrane forces (shell action). Hence in the thick shells where the load is distributed over a larger area than in the thin shells, relatively smaller membrane forces will occur than in thin shells. This is in accordance with the computed values for N_ϕ and N_x shown in Figs. 5 and 6, which are much smaller

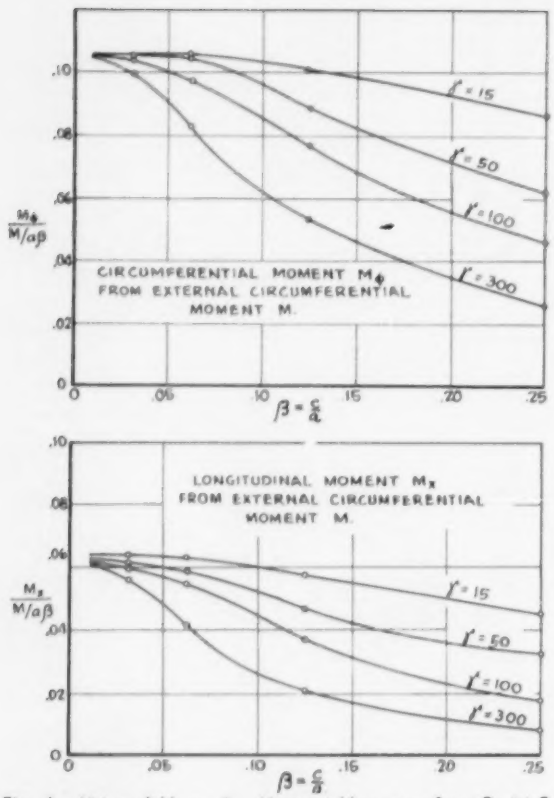


Fig. 4 $M\phi$ and M_x vs. β Moment M on a surface 2c × 2c on a cylindrical shell with radius a and length greater than a ($\gamma = a/t$)

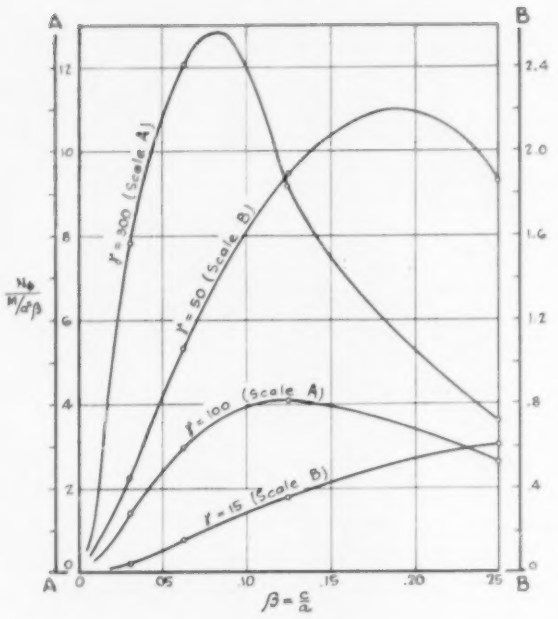


Fig. 5 $N\phi$ vs. β Circumferential membrane force from external circumferential moment M on surface 2c × 2c on a cylindrical shell with radius a and length greater than a ($\gamma = a/t$)

for small ratios $\gamma = a/t$ (thick shells) than for large ones (thin shells).

For values of γ between those for which the graphs have been drawn one has to interpolate. In general this should be done by drawing a small graph with γ as abscissa and the sought values as ordinates. For example to find θ for $\beta = 0.15$ and $\gamma = 65$, one reads $\theta/[M/(a^3\beta^2E)]$ from Fig. 3 for $\beta = 0.15$ and $\gamma = 15$, 50 and 100. One finds values of 84, 1940 and 11,200, respectively. Drawing a curve of $\theta/[M/(a^3\beta^2E)]$ vs. γ through the three points determined by these values one finds that, for $\beta = 0.15$ and $\gamma = 65$, $\theta = 3700\,M/(a^3\beta^2E)$.

The last 10 cases of Table 2 are loadings on rectangular surfaces. By finding from Figs. 3 to 6 the area of the square surfaces that give the same angle rotations and bending moments as the rectangular surfaces of Table 2, a method could be found for reducing a rectangular loading surface to an equivalent square area. The angle rotations and bending moments for rectangular loading surfaces are equal to those for square ones ($\beta_1 = \beta_2 = \beta$) from Figs. 3 and 4 when

$$\beta = K_c(\beta_1^2\beta_2)^{1/3} \qquad (1)$$

where K_c is given in Table 3 for θ, M_ϕ and M_x for various ratios β_1/β_2 and γ. Except the values in parentheses, all values have been directly computed from the results of Table 2. The values in parentheses were determined by an approximate calculation. It should be pointed out that, since all values K_c are based on Table 2, for example, $\beta_1/\beta_2 = {}^1/_4$ refers to $\beta_1 = {}^1/_{16}$ and $\beta_2 = {}^1/_4$. Hence, for other absolute values of β_1 and β_2 with the same ratio the values K_c are approximate. For other ratios than those in Table 3 one has to interpolate in the same way as shown above for determining θ. For calculating N_ϕ and N_x one finds these values from Figs. 5 and 6 for

$$\beta = (\beta_1^2\beta_2)^{1/3} \qquad (2)$$

and multiplies the values so determined with C_c from Table 3. It should be noted that the results are the larger, the smaller K_c is and the larger C_c is.

For off-center loading, at a distance x from the left end of the vessel (Fig. 1*a*), for the moments and membrane forces the graphs still apply if x is not smaller than ${}^1/_2a$. However, in using the graphs for the angle rotations one has to assume that the length of the vessel is equal to $4x(1-x)/l$ instead of its actual length l.

Effect of External Longitudinal Moments

The results for point R_1 in Fig. 2 are assembled in Tables 4 and 5. From Table 4, where all cases refer to *square* loading areas and a ratio $\alpha = 4$, the graphs in Figs. 7, 8, 9 and 10 are drawn, where the values from Table 4 are indicated by circles. Here similar remarks apply as were made in regard to Figs. 3 to 6, but there are some differences. By comparison of Figs. 3 and 7 one sees that the angle rotations in Fig. 7 are about of the order of only one-tenth of those in Fig. 3, so that a given shell is much more rigid against a longitudinal than against a circumferential external moment M. This may be easily understood by comparing Figs. 11 and 12. In Fig. 12, showing a longitudinal moment, from antisymmetry the circle CC will show no radial deflection, whence it is evident, that the load P will be carried more or less directly by membrane forces (shell action) to the rigid circle CC, as shown schematically in Fig. 12, while in contrast, under the loading in Fig. 11 the shell acts more as a plate. This explains the higher rigidity against the longitudinal moment in Fig. 12. Also, due to the greater benefit from the

Table 1—Circumferential Moment M

$\alpha = l/a = 4$

$\gamma = a/t$	$\beta_1 = \beta_2 = \beta$	$\Theta/(M/a^2\beta^2E)$	$M_\varphi/(M/a\beta)$	$M_x/(M/a\beta)$	$-N_\varphi/(M/a^2\beta)$	$-N_x/(M/a^2\beta)$
15	1/4	151.3	0.0866	0.0458	0.609	1.050
15	1/8	66.9	0.1004	0.0575	0.358	0.492
15	1/16	24.5	0.1059	0.0627	0.151	0.187
15	1/32	8.8	0.1060	0.0634	0.040	0.063
50	1/4	2,918	0.0620	0.0272	1.86	4.53
50	1/8	1,608	0.0883	0.0467	1.89	2.98
50	1/16	670	0.1046	0.0588	1.06	1.38
50	1/32	239	0.1053	0.0615	0.44	0.52
100	1/8	15,070	0.0463	0.0180	2.67	9.03
100	1/8	9,480	0.0766	0.0371	4.08	7.56
100	1/16	4,350	0.0970	0.0543	2.97	4.13
100	1/32	1,640	0.1038	0.0595	1.40	1.72
300	1/4	181,750	0.0258	0.0088	3.64	21.76
300	1/8	143,640	0.0531	0.0210	9.15	26.28
300	1/16	77,990	0.0828	0.0419	12.06	20.38
300	1/32	33,260	0.0995	0.0559	7.82	10.44

Table 2—Circumferential Moment M

$\gamma = a/t$	$\alpha = l/a$	β_1	β_2	$\Theta/(M/a^2\beta_1^2E)$	$M_\phi/(M/a\beta_1)$	$M_x/(M/a\beta_1)$	$-N_\phi/(M/a^2\beta_1)$	$-N_x/(M/a^2\beta_1)$
100	1	1/8	1/8	6,350	0.0716	0.0366	4.20	7.92
100	2	1/8	1/8	8,110	0.0762	0.0376	4.11	7.69
100	4	1/8	1/8	9,480	0.0766	0.0371	4.08	7.59
100	8	1/8	1/8	10,590	0.0786	0.0382	4.09	7.51
100	20	1/8	1/8	12,120	0.0791	0.0384	4.12	7.55
100	4	1/4	1/16	16,650	0.0615	0.0432	9.30	11.39
100	4	1/8	1/16	10,203	0.0931	0.0614	6.96	8.84
15	4	1/16	1/4	18.4	0.0480	0.0175	0.054	0.112
50	4	1/16	1/4	475.5	0.0455	0.0157	0.209	0.671
100	4	1/16	1/4	3,016	0.0433	0.0144	0.359	1.74
300	4	1/16	1/4	54,670	0.0387	0.0126	0.692	7.10
15	4	1/16	1/8	22.2	0.0768	0.0345	0.105	0.158
50	4	1/16	1/8	593	0.0732	0.0313	0.609	1.09
100	4	1/16	1/8	3,798	0.0694	0.0282	1.437	3.09
300	4	1/16	1/8	67,790	0.0598	0.0219	3.924	13.89

membrane action, for large ratios β the ordinates in Fig. 7 decrease with increasing β. Only for very small values of β the shell again acts as a plate, so that M_x in Fig. 8 approximates the same value of 0.11 $M/(a\beta)$ as M_ϕ in Fig. 4.

From the first 5 cases of Table 5 all values are seen to be independent of $\alpha = l/a$, so that Figs. 7 to 10 apply for any value of α not smaller than one. From the last 8 cases of Table 5, concerning loadings within rectangular areas, data have been determined for reducing rectangular areas to equivalent square ones. The angle rotations and bending moments are equal to those for square areas from Figs. 7 and 8 when

$$\beta = K_l(\beta_1\beta_2^2)^{1/4} \qquad (3)$$

where K_l is given in Table 6 for various ratios β_2/β_1. To find N_ϕ and N_x one has to determine these values from Figs. 9 and 10 for

$$\beta = (\beta_1\beta_2^2)^{1/4} \qquad (4)$$

and to multiply them with C_l from Table 6.

Figs. 7 to 10 also apply for off-center loadings at a distance x from the left end, if x is not smaller than $1/2\,a$.

The use of the graphs for obtaining the stresses will be shown in comparing the theory with the test results obtained by Schoessow and Kooistra. It may not be superfluous to add here, that for brittle fracture the maximum principal tensile stress is the governing quantity. In contrast, for plastic deformation or fatigue the distortion energy governs, which means that a plane state of stress σ_1, σ_2 has the same effect as an equivalent pure tensile or compression stress of magnitude $\sigma_i = (\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2)^{1/2}$, where σ_1 and σ_2 are the principal stresses.[3]

Dimensions of Reinforcing Pads

If the maximum stresses are higher than the allowable ones, one has to apply reinforcing pads. In that case one will want to know at which distance from the attachment the stresses are sufficiently small so that reinforcement can be discontinued. The determination of stresses outside the attachment was not part of the original program of this investigation, so that no stresses outside the attachment were computed from the exact formulas of Reference 2. However, since it is necessary to know how large these reinforcing pads have to be, in Reference 1 approximate formulas to this effect were given, which, of course, do not have the same reliability as the directly computed values for the maximum moments and membrane forces. It is with some reservations that here, too, an approximate method will be given for determining the bending moments and membrane forces outside the attachment. Experimental data on the effect of local reinforcement would be desirable to permit a check or modification of this method and might be utilized to develop a simplified approach. Part of the following formulas is based on the fact that, for example, the effect of a circumferential moment M can be considered as that of two loads $P_1 = P_2 = 3/4\,M/c_1$ (Fig. 13) acting within rectangles with sides $2/3c_1$ and $2c_2$. Hence the influence of a load P_2 on the stresses in Q_1, at a distance $k = (5/3)c_1$ from P_2, is equal to that of M, acting on a rectangle with sides $2c_2$ and $(8/3)k = 2c_1$, diminished with that of P_1, acting on a rectangle with sides $2c_2$ and $(2/3)k = (2/3)c_1$.

Trying to keep the resulting stresses on the conservative side, the moments and membrane forces at the edges of a reinforcing pad $CDEF$, with dimensions $2d_1$ and $2d_2$, in the circumferential and longitudinal directions, respectively, caused by a *circumferential moment* M acting upon an attachment with dimen-

Table 3—Circumferential Moment

β_1/β_2	γ	K_c for Θ	K_c for M_φ	K_c for M_x	C_c for N_φ	C_c for N_x
1/4	15	1.09	1.31	1.84	0.31	0.49
	50	1.04	1.24	1.62	0.21	0.46
	100	0.97	1.16	1.45	0.15	0.44
	300	0.92	1.02	1.17	0.09	0.46
1/2	15	1.00	1.09	1.36	0.64	0.75
	50	0.98	1.08	1.31	0.57	0.75
	100	0.94	1.04	1.26	0.51	0.76
	300	0.95	0.99	1.13	0.39	0.77
2	15	(1.00)	(1.20)	(0.97)	(1.7)	(1.3)
	100	1.19	1.10	0.95	1.43	1.12
	300	...	(1.00)	(0.90)	(1.3)	(1.00)
4	15	(1.00)	(1.47)	(1.08)	(1.75)	(1.31)
	100	1.49	1.38	1.06	1.49	0.81
	300	...	(1.27)	(0.98)	(1.36)	(0.74)

Table 4—Longitudinal Moment

$\alpha = l/a = 4$

$\gamma = a/t$	$\beta_1 = \beta_2 = \beta$	$\Theta/(M/a^2\beta^2E)$	$M_\varphi/(M/a\beta)$	$M_x/(M/a\beta)$	$-N_\varphi/(M/a^2\beta)$	$-N_x/(M/a^2\beta)$
15	1/4	56.5	0.0325	0.0502	1.686	0.587
15	1/8	36.6	0.0511	0.0842	1.290	0.345
15	1/16	16.3	0.0596	0.1015	0.614	0.147
15	1/32	5.9	0.0650	0.1073	0.223	0.053
50	1/4	607	0.0137	0.0172	4.09	1.94
50	1/8	617	0.0363	0.0548	5.72	1.84
50	1/16	370	0.0534	0.0881	3.95	1.03
50	1/32	160	0.0631	0.1031	1.79	0.43
100	1/4	1,960	0.0059	0.0070	5.22	3.06
100	1/8	2,650	0.0247	0.0338	10.68	4.09
100	1/16	2,020	0.0465	0.0737	10.15	2.88
100	1/32	1,000	0.0607	0.0976	5.52	1.36
300	1/4	9,100	0.000003	0.0008	6.26	4.16
300	1/8	20,110	0.0088	0.0102	18.78	10.35
300	1/16	23,500	0.0297	0.0419	33.50	11.88
300	1/32	16,150	0.0535	0.0807	27.95	7.64

Table 5—Longitudinal Moment

$\gamma = a/t$	$\alpha = l/a$	β_1	β_2	$\Theta/(M/a^2\beta_2^2E)$	$M_\varphi/(M/a\beta)$	$M_x/(M/a\beta)$	$-N_\varphi/(M/a^2\beta)$	$-N_x/(M/a^2\beta)$
100	1	1/8	1/8	2850	0.0273	0.0338	10.15	4.87
100	2	1/8	1/8	2770	0.0254	0.0340	10.65	4.20
100	4	1/8	1/8	2650	0.0247	0.0338	10.68	4.09
100	8	1/8	1/8	2700	0.0249	0.0337	10.66	4.10
100	20	1/8	1/8	2690	0.0249	0.0337	10.66	4.09
15	4	1/4	1/16	10.3	0.0147	0.0437	0.466	0.073
50	4	1/4	1/16	178.6	0.0104	0.0329	2.56	0.329
100	4	1/4	1/16	756	0.0068	0.0235	5.75	0.580
300	4	1/4	1/16	4550	0.0018	0.0086	13.06	0.483
100	4	1/8	1/16	1460	0.0209	0.0470	8.63	1.85
15	4	1/16	1/4	73.8	0.0849	0.0813	1.87	0.784
100	4	1/16	1/4	4570	0.0474	0.0281	7.16	6.75
100	4	1/16	1/8	3450	0.0519	0.0514	11.87	5.46

sions $(2c_1)$ $(2c_2)$, can be calculated as follows (Fig. 13):

The maximum moments and membrane forces at the edges *DC and EF* are equal to those from the same moment M if acting within a rectangle $(2c_1)$ $(2d_2)$ and can be calculated by using eqs 1 and 2, Table 3 and Figs. 4, 5 and 6.

The maximum moment and membrane forces at the *edge CF* are calculated as

$$(M_{\phi \text{ or } x} \text{ or } N_{\phi \text{ or } x})_M = (M_{\phi \text{ or } x} \text{ or } N_{\phi \text{ or } x})_{P_1} + (M_{\phi \text{ or } x} \text{ or } N_{\phi \text{ or } x})_{P_2} \quad (5)$$

where the subscripts M, P_1 and P_2 denote that the moments or membrane forces are caused by M, P_1 and P_2, respectively (Fig. 13). Hence the effect from M is considered as the sum of that from P_1 and P_2, where $P_1 = P_2 = (^3/_4)M/c_1$. With these notations $(M_\phi)_{P_1}$ can be determined from eq 4 and Figs. 5 and 9 of Reference 1, assuming the dimensions of the loading area, denoted[1] as $2c_1$ and $2c_2$, as $2c_{11} = (^2/_3)\,c_1$ and $2c_2$, respectively, with the present notations. As shown in Fig. 13 these are the dimensions of the surface where P_1 is assumed to act. The dimensions of the reinforcing pad, denoted in Reference 1 as $2d_1$ and $2d_2$ are here assumed as $2d_{11} = 2(d_1 - (^2/_3)\,c_1)$ and $2d_2$, respectively (Fig. 13). $(M_x)_{P_1}$ can be calculated from eq 6 and Figs. 6 and 9 of Reference 1, assuming the same dimensions $(2c_{11})$ $(2c_2)$ and

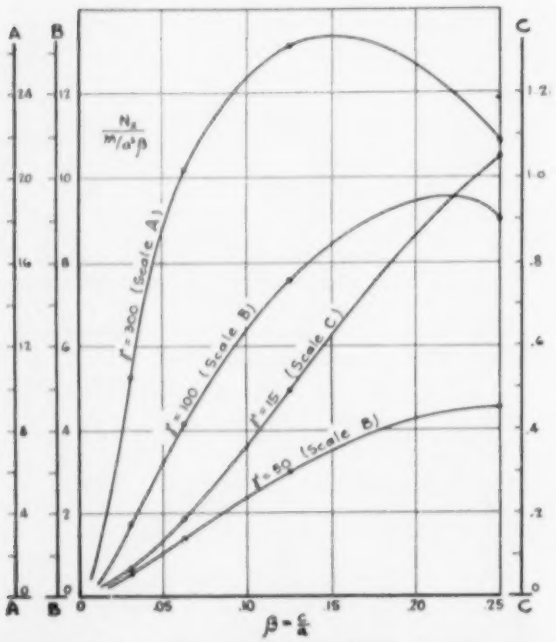


Fig. 6 N_x vs. β Longitudinal membrane force from external circumferential moment M on surface 2c × 2c on a cylindrical shell with radius a and length greater than a ($\gamma = a/t$)

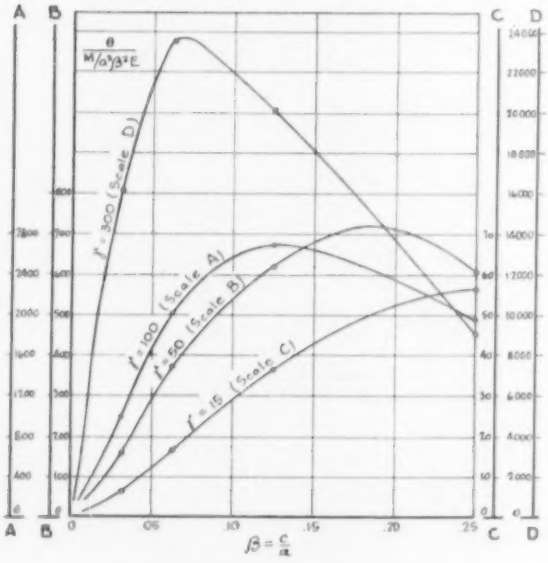


Fig. 7 θ vs. β Angle rotation from external longitudinal moment M on surface 2c × 2c on a cylindrical shell with radius a ($\gamma = a/t$)

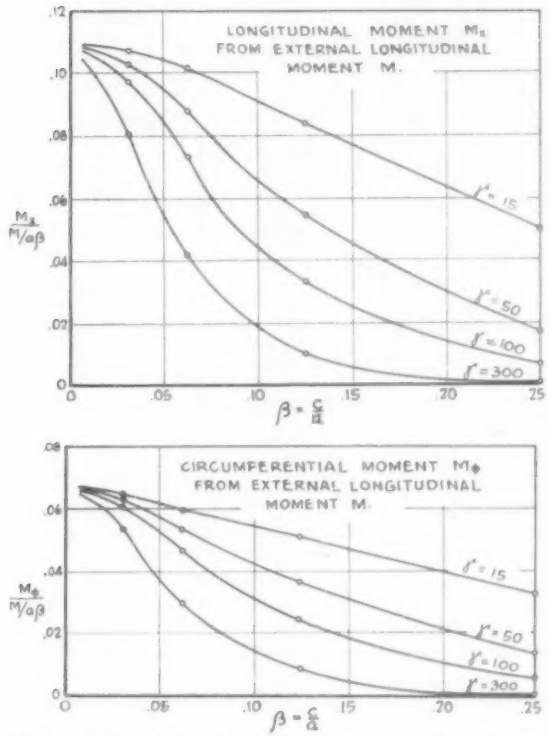


Fig. 8 $M\phi$ and M_x vs. β Moment M on a surface $2c \times 2c$ on a cylindrical shell with radius a and length greater than a ($\gamma = a/t$)

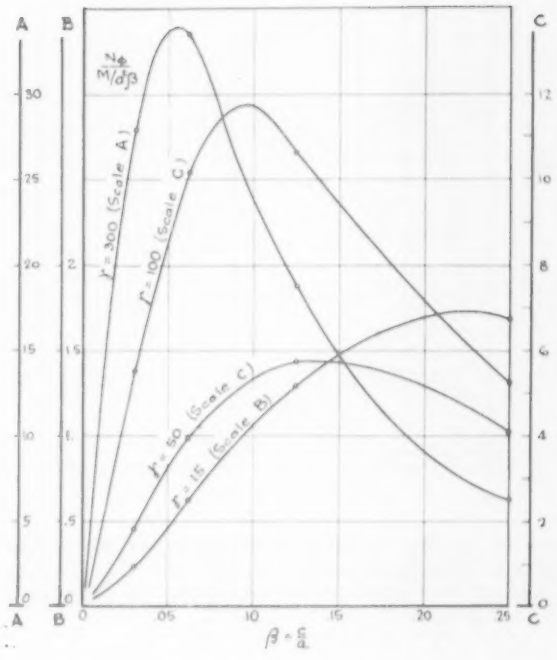


Fig. 9 $N\phi$ vs. β Circumferential membrane force from external longitudinal moment M on surface $2c \times 2c$ on a cylindrical shell with radius a and length greater than a ($\gamma = a/t$)

($2d_{11}$) ($2d_2$) of loading area and reinforcing pad, respectively. $(N_\phi)_{P_1}$ and $(N_x)_{P_1}$ are calculated for the same dimensions as indicated in Reference 1, that is, from Figs. 7, 8 and 9 of Reference 1 for a loading surface ($2d_{11}$) ($2d_7$).

The last term in eq 5 is calculated as

$$(M_{\phi \text{ or } x} \text{ or } N_{\phi \text{ or } x})_{P_2} = (M_{\phi \text{ or } x} \text{ or } N_{\phi \text{ or } x})_M - 0.85(M_{\phi \text{ or } x} \text{ or } N_{\phi \text{ or } x})_P \quad (6)$$

Here $(M_{\phi \text{ or } x}$ or $N_{\phi \text{ or } x})_M$ are the moments or membrane forces caused by a circumferential moment equal to (c_{12}/c_1) M, where $c_{12} = (^3/_4)$ $((^2/_3)$ $c_1 + d_1)$, acting within an area with dimensions $2c_{12}$ and $2c_2$, in the circumferential and longitudinal directions, respectively. Hence, these values can be determined by using eqs 1 and 2, Table 3 and Figs. 4, 5 and 6. Finally $(M_{\phi \text{ or } x}$ or $N_{\phi \text{ or } x})_P$ are calculated for a radial loading $P = (^3/_4)$ M/c within area with dimensions $2c_{12}$ and $2c_2$ in the circumferential and longitudinal directions, respectively, where $c_{12} = (^3/_4)$ $((^2/_3)$ $c_1 + d_1)$, using Figs. 5, 6, 7, 8 and 9 of Reference 1. The moment and membrane forces at the *edge DE* are, of course, equal and opposite to those at the edge *CF*.

For the moments and membrane forces from a *longitudinal moment M* the same method can be applied. In the preceding explanations referring to a circumferential moment and in Fig. 13 one has only to change c_1, c_2, c_{11}, c_{12}, c_{13}, d_1, d_2 and d_{11} to c_2, c_1, c_{21}, c_{22}, c_{23}, d_2, d_1, and d_{21}, respectively. Further in Fig. 13 the X and Y axes should be interchanged. Also, of course, for calculating the stresses at the edges *DC* and *EF*, now being parallel to the X axis, eqs 3 and 4, Table 6 and Figs. 8, 9 and 10 have to be used. $(M_\phi)_{P_1}$ is now calculated from eq 5 and Figs. 5 and 9 of Reference 1, $(M_x)_{P_1}$ from eq 7 and Figs. 6 and 9 of Reference 1 and $(N_\phi)_{P_1}$ and $(N_x)_{P_1}$ from Figs. 7, 8 and 9 of Reference 1. Finally $(M_{\phi \text{ or } x}$ or $N_{\phi \text{ or } x})_M$ from the present eq 6 are now determined from the present eqs 3 and 4, Table 6 and Figs. 8, 9 and 10 and $(M_{\phi \text{ or } x}$ or $N_{\phi \text{ or } x})_P$ are determined from Figs. 5, 6, 7, 8 and 9 of Reference 1.

It may be useful to emphasize here what is said following eqs 3 in Reference 1 about rectangular loading surfaces. Consider, for example, the rather unusual case that the reinforcing pad belonging to the hatched attachment ($2c_1$) ($2c_2$) is made much longer in the longitudinal than in the circumferential direction (Fig. 14). It would then be too inconservative to assume, in calculating the first terms of eqs 4 and 6 of Reference 1 or in calculating, for example, $(N_\phi)_{P_1}$ and $(N_x)_{P_1}$ in the present eq 5, that the load was distributed over the total area ($2d_1$) ($2d_2$) or ($2d_{11}$) ($2d_7$), since an extension of the flexible

Table 6—Longitudinal Moment

β_1/β_2	γ	K_1 for Θ	K_1 for M_ϕ	K_1 for M_x	C_1 for N_φ	C_1 for N_x
1/4	15	1.14	1.80	1.24	0.75	0.43
	50	1.13	1.65	1.16	0.77	0.33
	100	1.18	1.59	1.11	0.80	0.24
	300	1.31	1.56	1.11	0.90	0.07
1/2	15	(1.00)	(1.08)	(1.04)	(0.90)	(0.76)
	100	1.00	1.06	1.02	0.97	0.68
	300	(1.00)	(1.05)	(1.02)	(1.10)	(0.60)
2	15	...	(0.94)	(1.12)	(0.87)	(1.30)
	100	1.09	0.89	1.07	0.81	1.15
	300	...	(0.79)	(0.90)	(0.80)	(1.50)
4	15	1.39	0.90	1.24	0.68	1.20
	100	1.18	0.81	1.12	0.51	1.03
	300	...	(0.64)	(0.83)	(0.50)	(1.33)

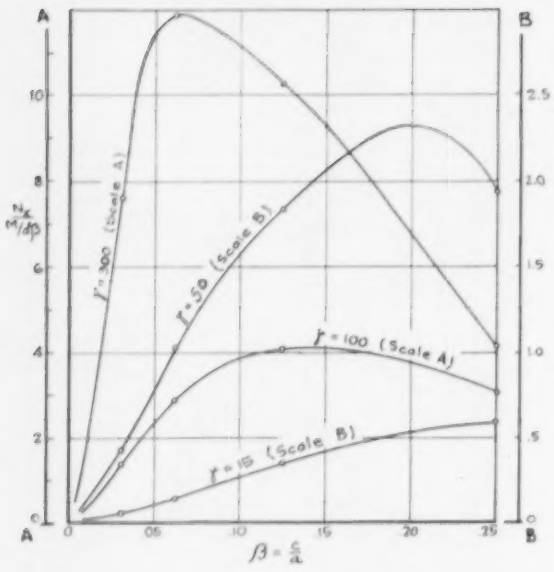


Fig. 10 N_x vs. β **Longitudinal membrane force from external longitudinal moment M on surface 2c × 2c on a cylindrical shell with radius a and length greater than a ($\gamma = a/t$)**

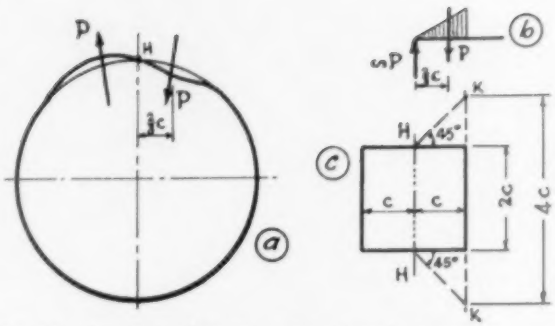


Fig. 11 Loading of shell by circumferential moment

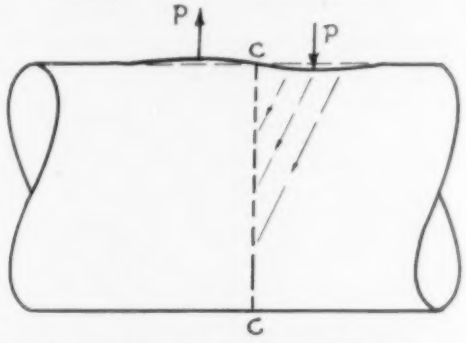


Fig. 12 Loading of shell by longitudinal moment

pad in the direction of d_2 only will practically not diminish the stresses in A. In such cases, to remain on the conservative side, it is better to assume d_2 equal to d'_2 in Fig. 14, where $d'_2 = (c_2/c_1)d_1$.

For nonrectangular attachments it seems logical to assume that the moments and membrane forces at the edges of the reinforcing pad are equal to those acting on lines that are located at the same distance from the equivalent rectangular loading surface as that of these edges from the actual attachment. For example, for a circular attachment the equivalent loading surface is the square *LMNO* in Fig. 15. Then the stresses at the edges *CDEF* of the reinforcing pad are assumed to be equal to those on the square C' D' E' F' that is situated a distance a–c inside the square *CDEF*.

Comparison with Tests by Schoessow and Kooistra

Since the stresses caused by external moments are very localized, the stresses caused by two equal and opposite moments at the ends of one diameter, as applied in the above tests,[4] will be practically equal to those from single moments, as assumed in the theory.[2] Assuming tentatively the pipe cross section to be equivalent to the circumscribed square, as proved to be satisfactory in the case of radial loadings,[1] the characteristics for the thin cylinder are

$\alpha = l/a = 71$ in./28 in. $= 2.536$
$\beta = c/a = 5.875$ in./28 in. $= 0.21$
$\gamma = a/t = 28$ in./1.3 in. $= 21.54$

Since α is larger than one, the graphs can be used. Considering a *circumferential external moment M* for finding a certain value, say M_ϕ, one first finds from Fig. 4 its value for $\beta = 0.21$ and $\gamma = 15$, 50 and 100, yielding $M_\phi = 0.0913$, 0.0695 and 0.0552 $M/(a\beta)$. Plotting M_ϕ vs. γ one then finds that for $\gamma = 21.54$, $M_\phi = 0.087$ $M/(a\beta) = 0.087$ M/c. Following the same procedure for M_x, N_ϕ and N_x one obtains the values assembled in Table 7. Since $M = 410{,}000$ in.-lb this gives $M_\phi = 6070$ in.-lb/in., $N_\phi = -2240$ lb/in. The stresses plotted in Figs. 9 and 10 of Reference 4 refer to point Q_2 in the present Fig. 1, while the computed values refer to point Q_1. Hence at point Q_2, $M_\phi = -6070$ in.-lb/in., $N_\phi = 2240$ lb/in., so that $\sigma_\phi = 6M_\phi/t^2 + N_\phi/t = 21{,}560 + 1720 = 23{,}280$ *psi*. The test results, extrapolated up to the intersection of pipe and vessel, are $\sigma_\phi = 25{,}000$ and 27,000 psi, from Figs. 9 and 10 of Reference 4, respectively. Further from Table 7, $M_x = -3140$ in.-lb/in., $N_x = 3990$ lb/in. and $\sigma_x = 14{,}220$ *psi* against $\sigma_x = 16{,}000$ and 23,500 psi, from Figs. 9 and 10 of Reference 4. Hence, the computed stresses are lower than the extrapolated measured ones.

For a *longitudinal external moment M* the values given in Table 8 are obtained.

This yields for point R_2 (Fig. 2) $M_\phi = -2408$ in.-lb/in., $N_\phi = 6980$ lb/in. and $\sigma_\phi = 13{,}910$ *psi* against extrapolated measured stresses of 13,500 and 13,000 psi from Figs. 11 and 12 of Reference 4. In the same way one finds $\sigma_x = 14{,}620$ psi against 16,500 and 16,000 psi from Figs. 11 and 12.

Although the agreement between theory and test results is very satisfactory, it would have been preferable if the computed stresses had been a little higher. The maximum distributed loads p (Fig. 1) caused by an external moment acting on a full circular attachment will be equal to those for a square attachment if both have the same section modulus. Hence, the equivalent value c for a circular attachment would follow from the equation $(2c)^2/6 = \pi r^2/4$ or $c = 0.838$ r, where r is the radius of the circular attachment. However this would give stresses that are generally higher than those found in the tests.

It seems therefore sufficiently accurate to choose here a middle course and to replace the attachment by a square with the same moment of inertia, so that $(2c)^4/12 = \pi r^4/4$ or $c = 0.875$ r. Then, in the present case, $c = 0.875$ $(5.875) = 5.14$ in. so that $\beta = c/a = 0.1835$. In the same way as shown above one now finds, from a *circumferential moment M*, $\sigma_\phi = 27{,}450$ *psi* against 25,000 and 27,000 psi from the tests, and $\sigma_x = 16{,}600$ *psi* against 16,000 and 23,500 psi from the tests. Since for ideal conditions the two test results should be equal, not too much value can be attached to the two latter test results. From a *longitudinal moment M* one obtains $\sigma_\phi = 16{,}710$ *psi* against 13,500 and 13,000 psi from the tests, and $\sigma_x = 18{,}760$ *psi*, against 16,500 and 16,000 psi from the tests.

Table 7

Source	Value	γ = 15	50	100	21.54	Factor
Fig. 4	M_ϕ	0.0913	0.0695	0.0552	0.087	M/c
Fig. 4	M_x	0.0493	0.0323	0.0227	0.045	M/c
Fig. 5	$-N_\phi$	0.565	2.16	3.37	0.90	$M/(ac)$
Fig. 6	$-N_x$	0.88	4.81	9.80	1.60	$M/(ac)$

Table 8

Source	Value	γ = 15	50	100	21.54	Factor
Fig. 9	M_ϕ	0.0385	0.020	0.010	0.0345	M/c
Fig. 9	M_x	0.060	0.027	0.0132	0.052	M/c
Fig. 10	$-N_\phi$	2.0	5.3	6.85	2.80	$M/(ac)$
Fig. 11	$-N_x$	0.54	2.3	3.75	0.90	$M/(ac)$

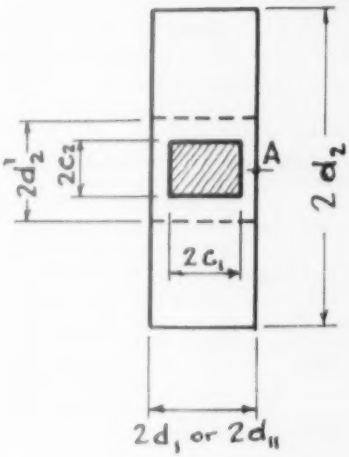


Fig. 14 Rectangular reinforcing pad

Hence for nonrectangular attachments the dimension c of the equivalent rectangle should be assumed such that its moment of inertia about the moment axis is equal to that of the plan of the actual attachment, so that *for tube attachments* $c = 0.875\ r$. In general it should be assumed that the dimensions of the rectangle in the longitudinal and circumferential directions have the same ratio as the two dimensions of the attachment in these directions.

Reduction of Deflections, Bending Moments and Membrane Forces by Internal Pressure

In Reference 2 also the case of a combination of external loads and internal pressure was considered, in which case eq 15 of Reference 2 applies. Assuming an internal pressure q that causes hoop stresses $\sigma_h = aq/t$ of 13,000 psi, the deflections, moments and membrane forces have been determined from radial loadings P for the exploratory cases listed in Table 9, where the bars above w, M_ϕ, etc., indicate that these values apply to cases with internal pressure. Behind each numerical result its value from Reference 1 for the case of zero internal pressure ($q = 0$) is given in parentheses. The reduction of all values by internal pressure is the more important, the larger γ and β are, that is, the thinner the shell and the larger the loading surface.

It appears that for thin shells the reductions caused by internal pressure are very important. This reduction is caused by the negative radial loading exerted by the membrane stresses aq/t and $aq/(2t)$ due to the changes of curvature. Hence, except for a factor that depends on the distribution of the curvatures and on the shape of the influence surfaces for the values considered, this reduction can be expressed in terms of the hoop stress and the maximum bending moments M_ϕ and M_x, since the latter are functions of the curvatures. Also, these actual moments $\bar{M}_\phi$ and $\bar{M}_x$ could be written in terms of the known moments M_ϕ and M_x without internal pressure. This leads to an approximate formula for the factor Δ by which the deflections, moments and membrane forces for cases without internal pressure can be divided to take account of internal pressure. For *radial loadings* P this factor is

$$\Delta = 1 + \rho\beta_1\beta_2\gamma^2(\sigma_h/E)[(1.7\ M_\phi/P) + (0.4\ M_x/P)] \quad (7)$$

where σ_h is the hoop stress, M_ϕ and M_x are the bending moments for the same loading without internal pressure and ρ is a factor that is given for square loading surfaces in Table 10. For example, $\bar{M}_\phi = M_\phi/\Delta$, $\bar{N}_\phi = N_\phi/\Delta$. These factors ρ have been chosen in such a way that using eq 7 one arrives at the computed values of Table 9. Hence the factors ρ will be more accurate the closer the hoop stresses from internal pressure are to 13,000 psi. For β smaller than $^1/_{16}$ the ρ factor for $\beta = {}^1/_{16}$ can be used. For rectangular loading surfaces no data are available, so

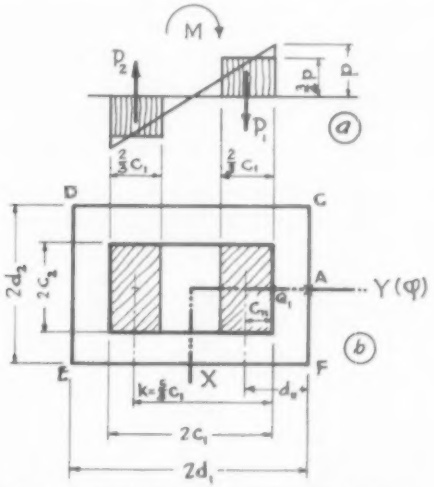


Fig. 13 Replacing of circumferential moment by radial loadings P_1 and P_2

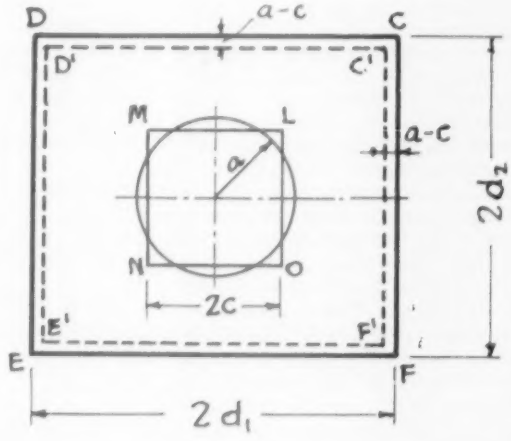


Fig. 15 Reinforcing pad for circular attachment

Table 9—Radial Loading, Combined with Internal Pressure Causing 13,000 psi Hoop Stress
(Figures refer to effects superimposed upon those from internal pressure only.)

$\alpha = l/a = 8$

$\gamma = a/t$	$\beta_1 = \beta_2 = \beta$	$w\frac{P}{Ea}$	M_ϕ/P	M_x/P	$-N_\phi/\frac{P}{a}$	$-N_x/\frac{P}{a}$
15	1/4	420(423)	0.077(0.077)	0.0485(0.0485)	1.713(1.820)	2.212(2.23)
	1/8	470(510)	0.141(0.145)	0.1092(0.1101)	2.482(2.60)	2.573(2.71)
	1/16	491	0.208(0.215)	0.1750	2.853	2.724
50	1/4	3600(5693)	0.0318(0.0439)	0.0153(0.0191)	2.840(3.123)	4.669(5.965)
	1/8	4503(6924)	0.0786(0.0967)	0.0543(0.0614)	6.109(6.482)	6.495(8.064)
	1/16	4946(7500)	0.1392(0.162)	0.1114(0.127)	8.357(9.10)	7.496(9.20)
100	1/8	9770(23,707)	0.0134(0.0291)	0.00543(0.0106)	3.086(3.676)	6.010(9.381)
	1/4	13,613(30,136)	0.0454(0.0716)	0.02943(0.0394)	8.998(9.792)	9.792(14.192)
	1/16	15,953(33,500)	0.0971(0.1350)	0.0796(0.094)	14.49(22)	12.43(17)
300	1/4	34,870(227,979)	0.00166(0.0140)	0.00057(0.0045)	2.98(3.713)	6.974(17.73)
	1/8	58,560(313,840)	0.01070(0.0406)	0.00665(0.0172)	12.566(14.96)	14.486(32.29)
	1/16	80,200(370,000)	0.0378(0.095)	0.0267(0.0455)	27.99(34.5)	23.045(47.0)

that, to avoid overestimating of the reduction, one could use the factors ρ from Table 10 for either β_1 or β_2, whichever is smallest. Since the deflection w includes the deflection as a beam, due to bending and shear, which is not diminished by internal pressure, the deflection w with internal pressure is expressed as

$$\bar{w} = w_b + (w - w_b)/\Delta \qquad (8)$$

where w is the deflection without internal pressure and w_b is the beam deflection, which, for a load in the center of the shell, can be written as

$$w_b = \left(\frac{\alpha^2}{48} + 0.65\right)\alpha\gamma\,\frac{P}{\pi Ea} \qquad (9)$$

Δ in eq 8 is given by equation 7, where ρ is given in the column for $(w\text{-}w_b)$ of Table 10.*

For loading by a *circumferential moment* M a similar formula as eq 7 can be derived for the division factor Δ,

$$\Delta = 1 + 0.45\rho\beta_1^2\beta_2\gamma^2(\sigma_b/E)[(1.7aM_\phi/M) + (0.4aM_x/M)] \qquad (10)$$

but no exact results have been computed yet to determine the factor ρ. One could, however, use the values of Table 10, if one assumes β equal to $^1/_2\,\beta_1$ or β_2, whichever yields the smallest ρ values. For loading by a *longitudinal moment*, in eq 10 $\beta_1^2\beta_2$ has to be changed to $\beta_1\beta_2^2$. Further, in Table 10, ρ should be sought for β equal to β_1 or $^1/_2\,\beta_2$, whichever gives the smallest value for ρ.

It should be noted, however, that on the other hand, due to the difference in rigidity between the attachment and the pure shell, the internal pressure alone causes complex local stresses around the attachments. The magnitude of these stresses is one of the other problems the Pressure Vessel Research Committee is studying. To be sure it is noted that in any case the membrane stresses from internal pressure alone have to be added to the stresses computed as indicated above.

Acknowledgment

This investigation was carried out at Cornell University under the sponsorship and with the financial assistance of the Design Division of the Pressure Vessel Research Committee of the Welding Research Council, Dr. E. Wenk, chairman, and B. E. Rossi and J. H. Drucker, past and present executive secretary, respectively. The advisory committee for this project consists of J. J. Murphy, chairman and W. E. Cooper, H. O. Hill, H. Liessenberg, G. J. Schoessow, A. M. Wahl, D. B. Wesstrom, members.

The numerical values in Tables 1, 2, 4, 5 and 9 have been computed mainly on IBM machines from the author's formulas given in Reference 2. The special coding for this case as well as the computation by the IBM 701 type calculator were done by Dr. Walter Murdock. This resulted in a relatively low cost of this numerical computation. A small part of the numerical calculations such as the computation of the series for case $m = o$, was done at Cornell University from similar closed formulas as eq 48, 49 and 50 of Reference 2, derived for the case of radial loading. The latter and other numerical calculations connected with the present paper were done mostly by M. Taheri, graduate student at Cornell University. The author wishes to thank all concerned for their valuable cooperation.

References

1. Bijlaard, P. P., "Stresses from Radial Loads in Cylindrical Pressure Vessels," The Welding Journal, 33 (12), Research Suppl., 615-s to 623-s (1954).
2. Bijlaard, P. P., "Stresses from Local Loadings in Cylindrical Pressure Vessels," *Transactions ASME*, 77, No. 6 (1955).
3. Bijlaard, P. P., "Some Remarks on the Influence of Residual Stresses on the Brittle, Plastic and Fatigue Behavior of Structures", in "Residual Stresses in Metals and Metal Construction," edited by W. R. Osgood, Reinhold Publishing Corp., New York (1954).
4. Schoessow, G. J., and Kooistra, L. F., "Stresses in Cylindrical Shell Due to Nozzle and Pipe Connections," *Transactions ASME*, 67, A-107 (1945).

Nomenclature

- a = radius of cylindrical shell
- c = half length of square loading surface
- c_1 = half length of rectangular loading surface in the circumferential direction
- c_2 = half length of rectangular loading surface in the longitudinal direction
- d_1 = half length of reinforcing pad in the circumferential direction
- d_2 = half length of reinforcing pad in the longitudinal direction
- l = length of shell
- p = distributed external pressure
- q = internal pressure

Table 10—Factor ρ in Equation (7) for Radial Loading

$\gamma = a/t$	β	$w - w_b$	M_φ	M_x	N_φ	N_x
15	1/4	11	0	0	34	11
	1/8	221	70	23	106	119
50	1/4	112	68	45	18	49
	1/8	178	71	40	20	77
	1/16	390	118	99	63	153
100	1/4	104	81	52	8.6	39
	1/8	139	63	37	9.5	49
	1/16	249	85	40	112	80
300	1/4	87	116	106	3.8	24
	1/8	53	33	19	2.3	15
	1/16	131	54	25	8.4	37

* In this connection it is noted that for finding the deflection for cases where α is larger than the maximum value α_m considered in Reference 1, one can add to the value for α_m the difference of the beam deflections for α and α_m, that is $w_\beta = [(\alpha^3 - \alpha_m{}^3)/48 + 0.65(\alpha - \alpha_m)]\gamma P/(\pi Ea)$.

t = wall thickness of shell
w = radial deflection
x = coordinate in longitudinal direction of shell
y = coordinate in circumferential direction of shell
C_c, C_l = multiplication factors for N_ϕ and N_x for rectangular surfaces given in Tables 3 and 6, respectively
E = modulus of elasticity
K_c, K_l = coefficients given in Tables 3 and 6 and used in eqs 1 and 3, respectively
M = external circumferential or longitudinal moment
M_ϕ, M_x = bending moments in shell wall in the circumferential and longitudinal direction, respectively
N_ϕ, N_x = membrane forces in shell wall in the circumferential and longitudinal direction, respectively
$\bar{w}$, $\bar{M}_\phi$, $\bar{M}_x$, $\bar{N}_\phi$, $\bar{N}_x$ refer to the case of simultaneous internal pressure
P = concentrated radial load or total distributed radial load
α = l/a
β = c/a
β_1 = c_1/a
β_2 = c_2/a
γ = a/t
θ = angle rotation
ρ = factor given in Table 10 and used in eqs 7 and 10
ϕ = cylindrical coordinate in circumferential direction of shell
σ_h = hoop stress from internal pressure q
σ_ϕ = stress in the circumferential direction
σ_x = stress in the longitudinal direction

REPORT OF THE FRENCH INSTITUTE OF WELDING

The annual Report of the French Institute of Welding for 1954 was issued by the President: Prof. A. Portevin on July 8, 1955.

Educational: The Institute's welding school has a class of 25 students. There were also evening and Saturday morning courses for a number of special groups. Certificates were issued to 946 specialized welders who studied at the professional welder's school.

Research: A study was made of the weldability of 15 heats of basic Bessemer steel low in metalloids and rimmed open-hearth steel. The study will be continued in 1955 and 1956 with further experimental heats:

Fatigue tests have been performed for the International Institute of Welding.

The Tee test for cracking was proposed to Committee IX of the IIW as an international standard weldability test.

The method of deoxidizing inert-gas-shielded mild-steel weld metal by spraying aluminum on the edges to be welded was developed. The method overcomes porosity.

The Gunnert method of measuring residual stress was applied to several problems. The method was recommended by the IIW. The method demonstrated the efficacy of the low-temperature stress-relieving process. Electric strain gages were used to measure stresses on the inside of tanks during hydraulic testing.

A program of tests on the strength of fillet welds was undertaken for Committee XV of IIW.

Ultrasonic inspection equipment was obtained for studying welds. Typical radiographs were procured for IIW. Some work was done on penetrameters for radiographs.

The role of hydrogen in causing cracks in air-hardening steels was studied for the Armament group.

The welding of concrete reinforcing bars was studied.

The Committee on Welding in Aeronautical Construction issued a specification on the spot and seam welding of steels and high-temperature alloys. The specification will be issued in 1955 and concerns materials, welding machines, controls and inspection of parts during manufacture. Work was done on the statistical analysis of the shear strength of spot welds.

Productivity Program: The General Committee on Productivity assigned Blair Moody aid for this new program which is in three parts. (1) A group of traveling engineers will be organized to acquaint industry in the possibilities of welding and allied processes in increasing productivity. Plants of various sizes were visited in the vicinity of Nantes and Paris. The different plants had very different methods of dealing with productivity. Some have gone far in the direction of time study and division of labor. However, our engineers rendered valuable aid in introducing new techniques, particularly inert gas welding. A special meeting, attended by 75 welding foremen, was held on December 17, 1954 at the Institute to demonstrate ways of increasing the productivity of welding equipment. Some of the subjects discussed at this meeting were large diameter electrodes, deep penetration electrodes and positioners.

(2) The second part of the program was the study of spot welding rusty and coated steel sheets. The study included work on torches to prepare the surfaces, apparatus for measuring the effect of torch treatment on contact resistance, and literature searches on the basic phenomena involved. A paper by Granjon and Evrard on this subject was awarded first prize by the Permanent International Acetylene Commission.

(3) Deep penetration methods for rapidly welding steel plates.

Translated from the French by Dr. G. E. Claussen.

MEASUREMENT OF SHUNTING CURRENTS IN SERIES SPOT WELDING 0.036-IN. STEEL

Effects of spot spacing, electrode and backing bar geometries, material preparation and electrode force on the size and distribution of shunt currents are studied

BY E. F. NIPPES, W. F. SAVAGE AND S. M. ROBELOTTO

ABSTRACT. The purpose of this investigation was to find the distribution and magnitude of the shunting or short-circuit currents in the series spot welding of 0.036-in. low-carbon auto body steel.

The effect on the short-circuit current of such variables as spot spacing, electrode geometry, backing bar geometry, stock preparation and electrode force was investigated. The apparatus used to measure the shunting currents is fully explained.

Introduction

In recent years, the higher production rates and other advantages peculiar to series spot welding have caused wider application of the process for fabrication of articles from mild steel sheet. Since series spot welding permits simultaneous production of two welds with each pulse of welding current from a given transformer secondary, a higher production rate is an inherent advantage of the process. Furthermore, the geometry of the welding circuit results in additional advantages for many applications. For example, the use of a copper backing bar on one side of the work to carry the current from one nugget location to the other results in a good surface finish with negligible surface distortion on this side. This feature is particularly attractive to manufacturers of automotive body components, since by placing the backing bar on the outside surfaces a smooth surface suitable for the subsequent painting operations is obtained. The fact that both welding electrodes contact the work from the same side is advantageous in some instances, since it often permits welding in otherwise inaccessible regions.

However, the process is not without attendant disadvantages. For example, three parallel current paths are available due to the geometry of the welding process. The total current is divided between the three such possible paths listed below:

1. Top sheet—A portion of the total current flows from one welding electrode longitudinally through the top sheet of the workpiece to the other electrode.
2. Bottom sheet—A portion of the total current flows from one welding electrode, through the thickness of the upper sheet, through the nugget area to the lower sheet, then through the lower sheet to the other nugget area and back through the upper sheet to the other electrode.
3. Backing bar—The major portion of the welding current should flow from one electrode, through both workpieces to the backing bar, then through the backing bar to the other nugget area and back through the work to the other electrode. The shunt current in the top sheet is disadvantageous in that:
   - (*a*) It contributes nothing to the production of the welds.
   - (*b*) It represents a loss, therefore increasing the over-all power requirements.
   - (*c*) It increases the current density in the electrodes when producing a given weld diameter, and therefore shortens electrode life.

Since little fundamental information was available on the effect of welding variables on the size and distribution of the shunt currents, the following research was conducted.

Object

The object of this investigation was to study the effect of spot spacing, electrode geometry, backing bar geometry, material preparation, and electrode force on the size and distribution of the shunt currents in series spot welding.

Material

Cold-rolled 0.036-in. rim steel, of the type generally used for automotive body components, was used in this investigation. The steel, supplied by Ford Motor Co., was covered with a protective film of oil and was essentially free of rust, dirt, and other foreign substances. Both as-received and degreased-and-pickled stock were used in the study.

The chemical analysis and mechanical properties of the material are presented in Table 1.

Table 1—Chemical Analysis and Mechanical Properties of Material Used

Chemical analysis	
Element	%
Carbon	0.055
Manganese	0.33
Silicon	0.01
Phosphorus	0.01
Sulfur	0.035
Copper	0.09
Nickel	0.05
Chromium	0.01
Molybdenum	0.01

Mechanical Properties	
Tensile strength, psi	46,500
Yield strength (0.2%), psi	32,300
Elongation in 2 in., %	28.0

Material Preparation

The specimens were degreased with acetone, pickled for 20–30 sec in 50% HCl solution, water rinsed, alcohol rinsed and dried thoroughly so as to obtain as low a contact resistance as possible. The contact resistance was measured by a modified Kelvin double bridge using a small hydraulic press fitted with electrodes to apply an electrode force. The specimens were clamped between the two electrodes with a force of 1000 lb, a 60-amp current was passed through the circuit, and the potential across the two sheets was balanced with the Kelvin double bridge. The contact resistance could then be read directly in microhms. It was important to keep the contact resistance as consistent as possible because of its influence on the shunting current. A range of 10–20 microhms was considered as acceptable.

E. F. Nippes, W. F. Savage and S. M. Robelotto are associated with the Welding Laboratory, Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

Equipment

Welding Equipment

The equipment, furnished by Fisher Body Division of the General Motors Corp., was installed in a frame constructed at Rensselaer Polytechnic Institute for a previous investigation.[1] Figure 1 shows the arrangement of the equipment.

In detail, the electrode force in this equipment was supplied to a pressure equalizing manifold and guns by an air hydraulic system as shown in Fig. 2. The electrical system consisted of a 50-kva Hypersil transformer with tap switch, RWMA class 2 electrodes, and a copper backing bar with removable stools. The arrangement of the electrodes is shown in Fig. 2. The transformer had two secondary windings of equal impedance and was rated at 440 v primary with the secondary voltage being regulated in approximately 8 equal steps from 4.58 to 6.88 v.

The power to the Hypersil transformer was supplied by a 125-hp, 350-kva motor-generator set operating from a three-phase, 4160-v, 60-cycle line. The output voltage of the single-phase, 60-cycle generator was adjustable from 250 to 550 v. Electronic controls were used for weld timing, and in all instances full phase (100% heat) current was used. Welding current was measured by means of a General Electric I^2T meter, and welding time was recorded by use of a Brush self-inking oscillograph.

Equipment for Measuring Shunting Current

The most vexing problem in this investigation was the determination of a method of measuring the shunting currents. It was apparent that a recording instrument was required because the welding time was extremely short (12 cycles of alternating current). Since flat sheets were being welded, a spreading effect of the current occurred through the sheet. Due to the spreading effect of the current, it was obvious that point contacts on the sheets would not give a true indication of the magnitude of the current. Only an air-core transformer, encompassing the full sheet width, could reliably measure the spreading current.

The operation of an air-core transformer depends on the fact that in the vicinity of a conductor-carrying alternating current there exists an alternating magnetic field whose intensity is proportional to the current. As a result of this magnetic field, a voltage will be induced in the air-core transformer proportional to the rate of change of the current producing the magnetic field. In order to convert this output signal to a voltage proportional to the instantaneous current, it is therefore necessary to employ an electronic integrating circuit. The output of the integrator is then amplified to obtain a more readily recorded signal amplitude.

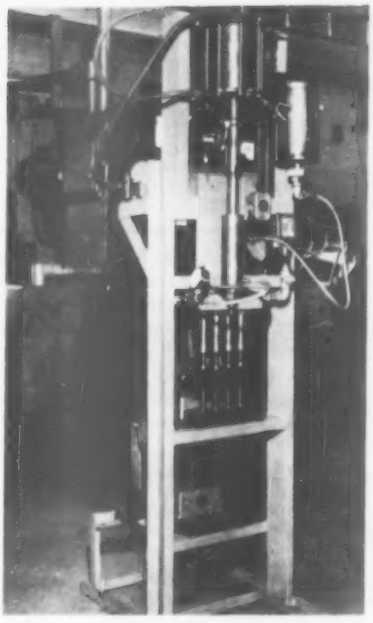


Fig. 1 Series spot-welding equipment

Commercial air-core transformers, being constructed in ring form, would either have to be large to engulf the sheet of steel or the sheet would have to be narrow enough to fit in a small toroid. The first of these two methods requires considerable bending of the sheet stock to allow insertion of the toroid, and this causes an undesirably large increase in the length of the current path. The second alternative above would require a narrow sheet, thus restricting the cross section of the workpiece and disturbing the system. Furthermore, with a closed ring toroid, the toroid would be between the sheets with a weld on either side of it after completion of the test. This would make removal cumbersome and time-consuming, since the weld would have to be broken. It was therefore felt that the open end, flat-shaped "U" toroids, described hereafter would be the better choice.

Two air-core toroids were constructed by hand winding 0.0113-in. Formex magnet wire on 1-ft lengths of $^1/_8$-in. Lucite,

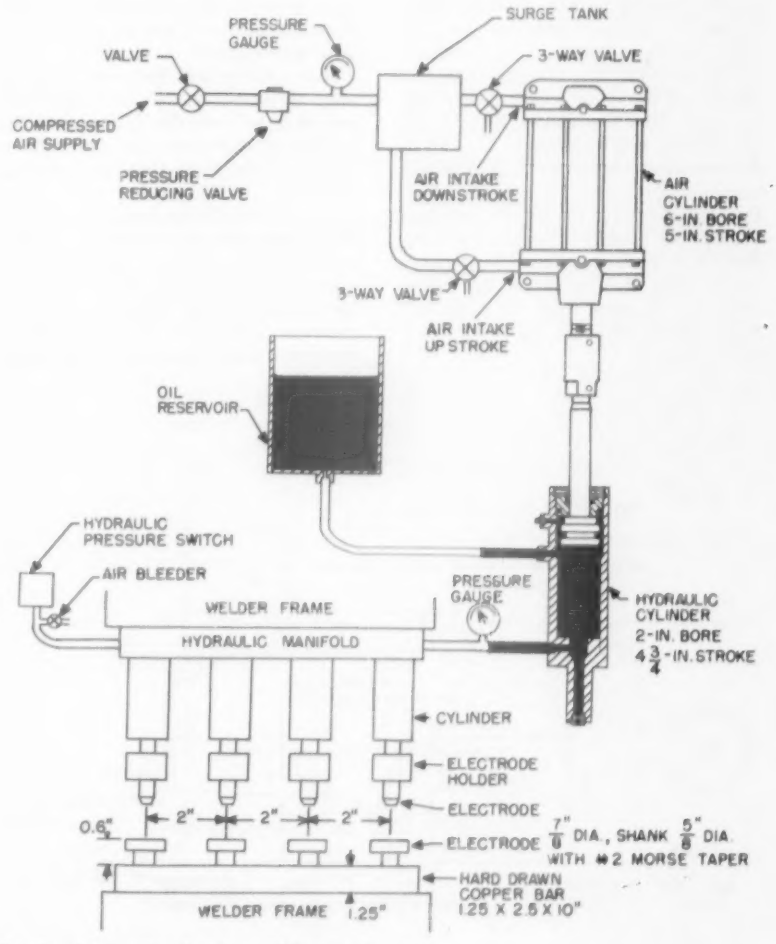


Fig. 2 Schematic of series welding equipment

0.6 in. wide. The wire was rewound upon itself to prevent the toroid from acting as a single loop and to increase sensitivity. The entire toroid was liberally coated with Collodion Flexible to hold the wire in position during the bending operation. The bending was accomplished by carefully heating the Lucite over a Bunsen burner and bending the toroid into the form of "U" when the plastic became soft. Details of these "U" toroids are shown in Fig. 4.

A two-channel, class A amplifier, with a cathode follower for each channel to match the impedance of the amplifier to that of the galvanometers in a Consolidated electromagnetic oscillograph, was constructed for amplifying the output of the toroids. All grid circuits were shielded to eliminate pick-up which was encountered with a preliminary amplifier design. A schematic of the equipment is shown in Fig. 3, and a parts list is given in Table 2.

Table 2—List of Parts for Integrating Amplifier

Transformer	*Tubes*	*Filters, henries*	*Resistors, ohms*	*Capacitors, μf*
A-c, v 325-0-325	6SQ7	12	0.1 meg	0.5
D-c, ma 55	6SL7	12	7 K	2
Rectifier fil.—5v, 2 amp	5Y3		0.5 K	0.003
Other volts, 6.3 C. T.			0.2 meg	20
Winding amp, 2			1.2 K	20

Calibration of Shunt Current Measuring Equipment

The toroids and amplifier were calibrated by use of a 220-v line connected to the primary of the welding transformer. A variable resistance and an ammeter were placed in the primary circuit so that the current could be varied and measured. A copper sheet, insulated from the backing bar circuit, was placed in the welder so that all of the secondary current went through the copper sheet. The "U" toroids were then placed around the copper sheet and a plot was made of galvanometer deflection vs. current. This was repeated using a steel sheet in place of the copper sheet to be sure that the magnetic properties of the stock would not affect the results.

The above setup was capable of passing a maximum of 3000 amp in the secondary circuit. To increase the range of calibration, the primary was connected to the welding-supply generator and a current of 7800 amp (the minimum available with the generator and welding transformer) was passed through the secondary circuit. Since the lower portion of the plot was a straight line, it was extended to the 7800-amp range and found to coincide with the point obtained with the welding-supply generator.

During calibration, investigations showed toroid output to be independent of position. By this it is meant that the flat face of the toroid did not necessarily have to be parallel to the surface of the sheet nor did the output depend upon the depth to which the sheet was placed in the toroid so long as the entire sheet was engulfed.

Some pickup was observed, however, when the toroid was placed in the magnetic field between the electrodes. The method of calibration described above minimized the error introduced by the pickup.

A commercial ring toroid was found which had sufficient windings (12,500) to provide an adequate output voltage without amplification. In fact, a voltage divider circuit had to be used in order to reduce the output signal to prevent overloading the recording equipment. The large signal obtained from the ring toroid was in part due to the fact that it was placed around one electrode to measure the total current which was considerably higher than the shunting currents measured by the "U" toroids during welding.

In order to have an independent method of measuring secondary current, an accurately calibrated Manganin shunt with high current capacity was placed in the secondary circuit. By connecting the shunt to the Consolidated oscillograph, the secondary current could be determined from the record of the millivoltage developed across the shunt by the welding current. Excellent agreement was obtained with these three methods of measuring the welding current described above: the I^2T meter, the secondary shunt and the ring toroid.

When dynamic measurements were made of the shunting currents and the current through the backing bar, the total of the three agreed within 5% of the total measured current; thus indicating that the accuracy of measurement of the shunting current is within ±5%.

A die was constructed for pressing the smallest possible offset in the stock which would allow the toroids to be inserted between the sheets, thereby minimizing the change in length of the shunt current paths during measurement.

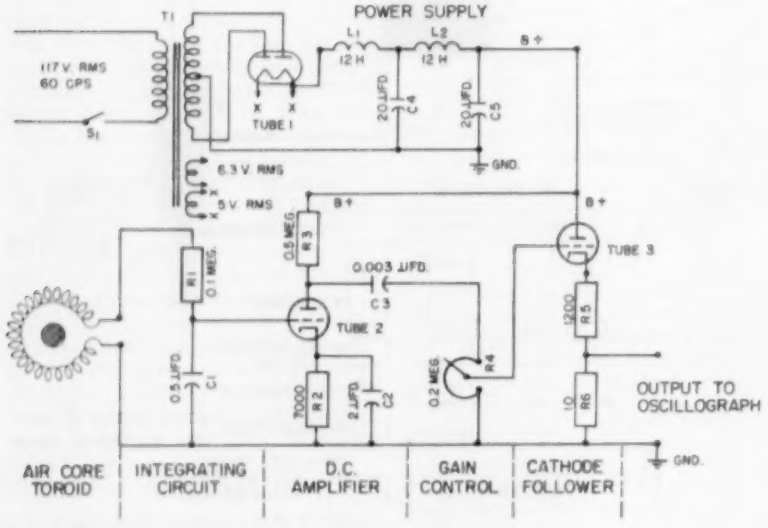


Fig. 3 Schematic diagram of integrating amplifier

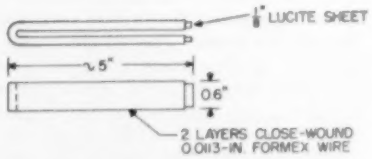


Fig. 4 Details of "U" toroids

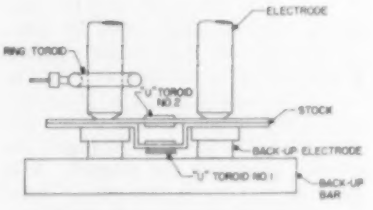


Fig. 5 Schematic of toroid method for measuring shunt currents

Procedure

With the use of channeled sheets, an air-core transformer could be placed on each of the sheets for measuring the shunting currents, and a toroid placed around one of the electrodes for measuring the total current as shown in Fig. 5. Thus knowing the total current and the shunting current in each sheet, the current in the backing bar may be calculated. The ring toroid could also be placed on the backing stool to measure the current in the backing bar. This method was applied originally, but it was realized that if a bend were placed in only one sheet the disturbance to natural welding conditions would be decreased. Hence, with the bend in the upper sheet, the toroid was placed around the lower sheet and the lower-sheet shunt current measured. With the bend in the lower sheet, the current in the upper sheet was measured. Ten welds were made for the measurement of the current in the lower sheet, and ten welds were made for measurement of the current in the upper sheet. An average was obtained for the current in each sheet, and this is the value presented in the tables.

Results

The current distribution during a 12-cycle weld is illustrated in Fig. 6. For a given welding condition the current in the lower sheet showed a maximum variation of approximately 100–200 amp from the beginning to the end of the weld period. In the upper sheet, a high current flow occurs for the first three cycles of current, rapidly decreases for the next six cycles, and then approaches a constant value for the remaining three cycles. All tabulated data in this report are given in terms of maximum current and minimum current for the first and last three cycles, respectively. The observed decrease in shunt current through the upper sheet may be explained as follows:

1. The initial resistance across the sheet-to-sheet faying surface is determined by the surface-contact resistance, and is of significant magnitude compared with the resistance of the shunt path through the upper sheet. This explains the relatively high shunt current at the beginning of welding.
2. The flow of shunt current through the upper sheet causes Joule heating of the stock and therefore an increase in the resistance of the shunt path, and a slight decrease in shunt current.
3. As soon as a molten nugget is formed the surface contact resistance decreases sharply and a continuous current path is provided from sheet to sheet. The resistance of this newly formed path appears to decrease as the size of the nugget grows, thus causing a further decrease in the shunt current through the upper sheet.

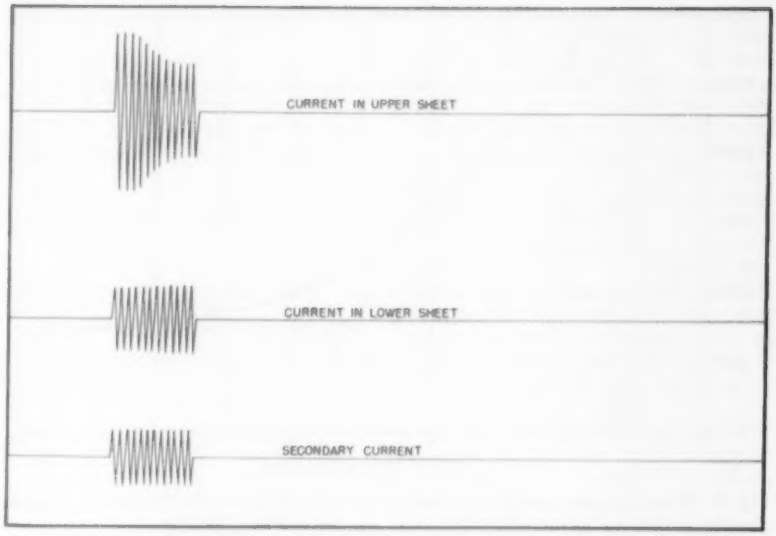


Fig. 6 Sketch of oscillogram showing shunting-current distribution in upper and lower sheet for 12-cycle weld; 10,700-amp secondary current

Effect of Electrode Spacing

Table 3 presents the data obtained for 2-, 4- and 6-in. electrode spacings using a $^{7}/_{32}$-in. restricted diameter, 6-in. radius electrode, a 1-in. diam flat backing electrode, a 10- x $2^{1}/_{2}$- x $1^{1}/_{4}$-in. backing bar, and 10,700 amp welding current. As may be seen from this table, the shunting current is reduced considerably as the spot spacing is increased. It might be thought that since the proportional resistance is the same for the backing bar and the two sheets being welded for each of the electrode spacings, the shunting currents should be the same for each of the spacings, provided the welding current is constant; but this is not true. The results may be explained by considering the influence of contact resistance which remains constant while the resistance of the backing bar and the two sheets increases with increased electrode spacing. The contact resistance between the lower sheet and backing electrodes plus the contact resistance between the backing electrodes and backing bar comprises the largest portion of resistance in the backing circuit. Thus in going from a 2- to a 4-in. electrode spacing, the backing circuit resistance does not double but increases by some smaller percentage; whereas the resistance of the sheets has doubled. Approximate calculations were made to verify this explanation.

It also may be observed that there is a greater effect in going from the 2- to the 4-in. electrode spacing as would be expected than there is in going from the 4- to the 6-in. spacing. This also tends to confirm the above explanation since it is obvious that as the electrode spacing increases the effect of contact resistance would diminish. It is expected that if greater spacings could be obtained and a plot made, the appearance of the graph would be as shown in Fig. 7.

Effect of Electrode Geometry

Three electrode geometries, Fig. 8, were used to study the effect of elec-

Table 3—Effect of Electrode Spacing on Shunting Current

	Current in upper sheet, amp	*Current in lower sheet, amp*	*Current in backing bar, amp*
2-in. electrode spacing, total current 10,700 amp			
First 3 cycles	3200	2000	5500
Last 3 cycles	2200	2100	6400
4-in. electrode spacing, total current 10,700 amp			
First 3 cycles	2300	1600	6800
Last 3 cycles	1750	1700	7250
6-in. electrode spacing, total current 10,700 amp			
First 3 cycles	1800	1450	7450
Last 3 cycles	1450	1500	7750

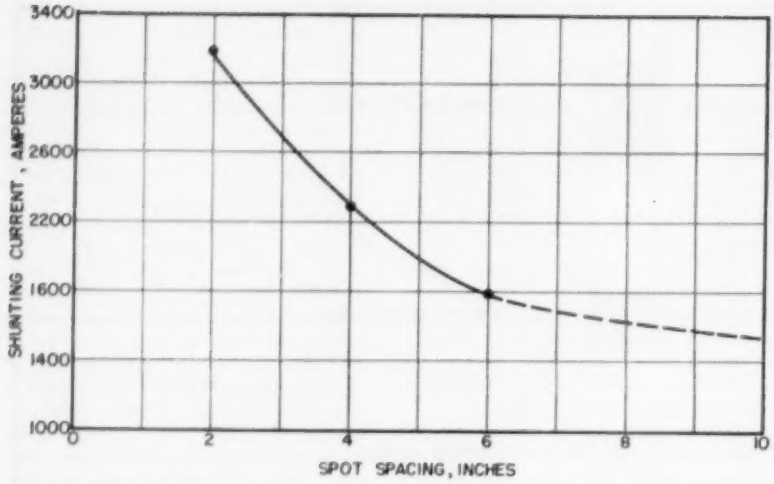


Fig. 7 Effect of spot spacing on shunting current plotted for first 3 cycles. Upper sheet—secondary current: 10,700 amp; electrode force, 380 lb

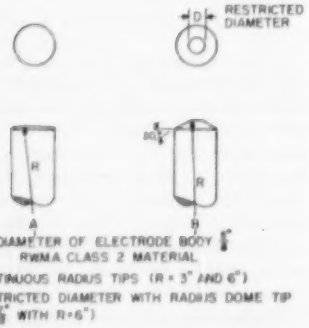


Fig. 8 Electrode geometries investigated

trode geometry on shunting currents: a 3-in. continuous radius; a 6-in. continuous radius; and a $^{7}/_{32}$-in. restricted, 6-in. radius electrode. Table 4 indicates the similar results obtained for the three electrodes, illustrating that electrode geometry had little or no effect on the shunting current.

Effect of Backing Bar Geometry

As stated previously, the backing circuit resistance consisted mostly of the contact resistances of the backing electrode and the lower sheet. It was therefore assumed that the greatest effect on the shunting current would be the elimination of the contact resistance between the backing electrode and backing bar by removing the backing electrode and using a solid block of copper. In order to allow the placing of the pick-up coil about the lower sheet, a slot $^{3}/_{4}$ x $^{3}/_{4}$ in. was machined in a $3^{3}/_{8}$- x $2^{1}/_{4}$- x $2^{1}/_{2}$-in. copper block, as shown in Fig. 9 (*A*). Using a solid copper backing bar without backing electrodes decreased the current in the upper sheet (Table 5) by 200 amp and decreased the current in the lower sheet by 600 amp for the 2-in. electrode spacing.

To find what effect the notch in the new backing bar had on the shunting current, the sheets were placed on the bar and the current measured only in the upper sheet. It was again measured in the same fashion with the block inverted, Fig. 9 (*B*), so that the lower sheet would lie on the solid portion of the bar. The results were in excellent agreement, indicating that the notch had relatively no effect.

Two other backing bar geometries, illustrated in Fig. 10, were used as a check against the effect of backing bar geometry without the use of backing stools. A solid copper bar with dimensions of $^{1}/_{2}$ x $^{1}/_{2}$ x 6 in. and a $^{3}/_{8}$- x $2^{1}/_{4}$- x $2^{1}/_{2}$-in. Mallory 3 (RWMA Class 2 electrode material) backing bar with a a $^{3}/_{8}$- x $^{3}/_{4}$-in. slot were used. The current in the upper sheet only was measured for the solid copper bar, and the currents in the upper and lower sheets

Table 4—Effect of Electrode Geometry on Shunting Current

2-in. electrode spacing, total current 10,700 amp

	Current in upper sheet, amp	*Current in lower sheet, amp*	*Current in backing bar, amp*
	$^{7}/_{32}$-in. restricted, 6-in. radius electrode		
First 3 cycles	3200	2000	5500
Last 3 cycles	2200	2100	6400
	3-in. continuous radius electrode		
First 3 cycles	3240	2050	5410
Last 3 cycles	2300	2150	6250
	6-in. continuous radius electrode		
First 3 cycles	3260	1900	5540
Last 3 cycles	2300	2000	6400

Table 5—Effect of Backing Bar Material and Geometry on Shunting Current

2-in. electrode spacing, 10,700-amp welding current

	Current in upper sheet, amp	*Current in lower sheet, amp*	*Current in backing bar, amp*
	(*A*) 10- x $2^{1}/_{2}$- x $1^{1}/_{4}$-in. copper backing bar with removable backing electrodes		
First 3 cycles	3200	2000	5500
Last 3 cycles	2200	2100	6400
	(*B*) $3^{3}/_{8}$- x $2^{1}/_{4}$- x $2^{1}/_{2}$-in. copper backing bar with slot $^{3}/_{4}$ x $^{3}/_{4}$-in., no backing electrodes		
First 3 cycles	3000	1400	6300
Last 3 cycles	2100	1580	7020
	(*C*) $^{3}/_{8}$- x $2^{1}/_{4}$- x $2^{1}/_{2}$-in. Mallory backing bar with slot $^{3}/_{4}$ x $^{3}/_{4}$-in., no backing electrodes		
First 3 cycles	2900	1520	6280
Last 3 cycles	2160	1620	6920
	(*D*) Sheets insulated from backing bar		
			Total current, amp
First 3 cycles	5700	5140	10,840
Last 3 cycles	4700	4200	8,900
	Measurement of current in upper sheet with bend in upper sheet		
	Backing bar B, slot up	*Backing bar B, slot down*	*Copper backing bar, $^{1}/_{2}$ x $^{1}/_{2}$ x 6 in.*
First 3 cycles	2860	2850	2980
Last 3 cycles	1960	1920	1940

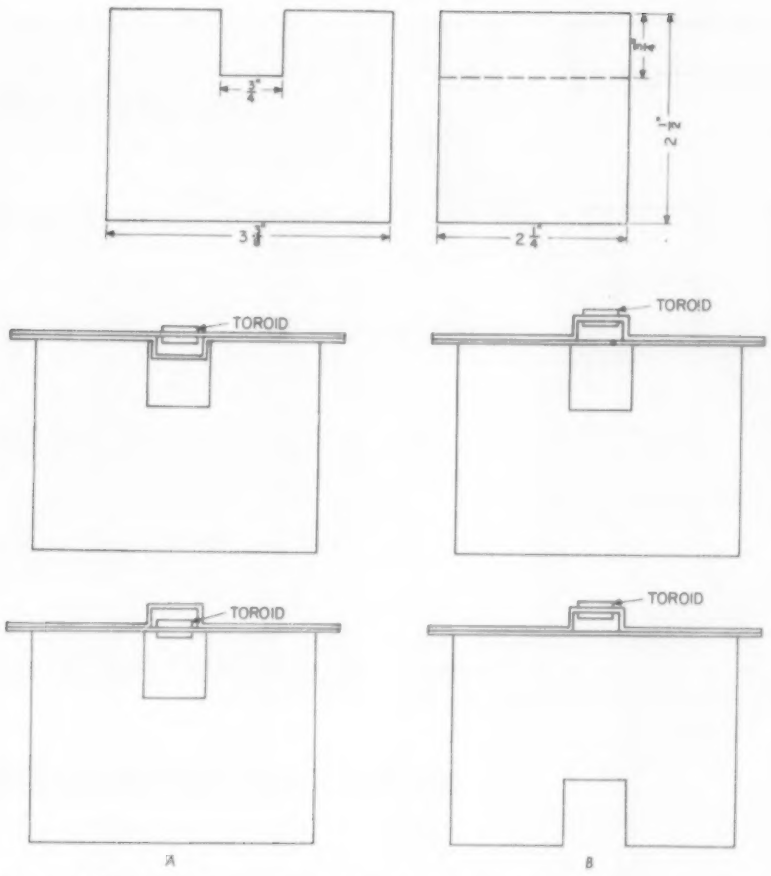


Fig. 9 (A) Method of measuring shunting current without backing electrodes (copper backing bar). (B) Method of measuring effect of notch on shunting current

were measured for the Mallory 3 backing bar. It may be observed from Table 5 that the results were quite similar to the previous backing bar without the backing stools, indicating that backing bar material or geometry had little effect on the shunting current.

When the sheets were insulated from the backing bar, all the current had to pass through the sheets. It may be seen from Table 5 that a greater percentage of current passes through the upper sheet due to the contact resistance and that the total current at the end of the weld period had decreased due to the increased resistance of the stock arising from the heating effect. It might be added that only incipient sticking occurred because the current flow through the contact was limited to about 40 percent of the total current.

Effect of Force on Shunting Current

As shown in Table 6, increasing the force from 380 to 500 lb on the degreased-and-pickled stock had a small effect on the shunting current. However, when as-received stock was used, increasing the force to 500 and 750 lb noticeably decreased the shunting current. A comparison between shunting currents and force is made in Table 6. It must be kept in mind, of course, that the maximum force which may be used is limited by the mushrooming of the electrodes.

Conclusions

1. At the initial stages of the weld, for 2-in. spot spacing, the lower sheet had about 1200 amp less flowing in it than the upper sheet; for the 4-in. spacing, 700 amp less, and for the 6-in. spacing 450 amp less. In all cases, however, at the end of the weld cycle the current flowing in the upper sheet and the lower sheet were about equal.

2. As might be expected from the percentage change in length of the shunt path, there was a greater decrease in the shunting current in going from the 2- to 4-in. weld spacing than in going from the 4- to the 6-in. spacing.

3. Electrode geometry had no effect on the shunting current.

4. The substitution of a solid copper backing bar for one with removable backing electrode significantly reduced the shunt current in the lower sheet.

5. A solid backing bar machined from RWMA Class 2 electrode material was found to reduce the shunt current in the lower sheet to about the same extent as the solid copper bar.

6. With a 2-in. electrode spacing and a force of 380 lb, the shunting current for the as-received material was considerably higher than for the pickled-and-degreased. The initial shunting current was 900 and 400 amp higher for the upper and lower sheets, respectively. At the end of the weld period, however, the current was approximately the same for the two conditions of stock.

7. Increasing the force on the pickled-and-degreased stock had little effect on the shunting current. Increasing the force on the as-received stock had the greatest effect on decreasing the shunting current in the upper sheet. There was, to a less degree, a decrease of current in the lower sheet.

Acknowledgments

The authors wish to acknowledge the

Table 6—Effect of Electrode Force on Shunting Current

	Current in upper sheet, amp	*Current in lower sheet, amp*	*Current in backing bar, amp*
	Degreased-and-pickled stock, 380 lb		
First 3 cycles	3200	2000	5500
Last 3 cycles	2200	2100	6400
	500 lb		
First 3 cycles	3000	1920	5780
Last 3 cycles	2150	2020	6530
	As-received stock, 380 lb		
First 3 cycles	4140	2490	4070
Last 3 cycles	2100	2150	6450
	500 lb		
First 3 cycles	3870	2360	4470
Last 3 cycles	2050	2080	6570
	750 lb		
First 3 cycles	3770	2200	4730
Last 3 cycles	2000	2000	6700

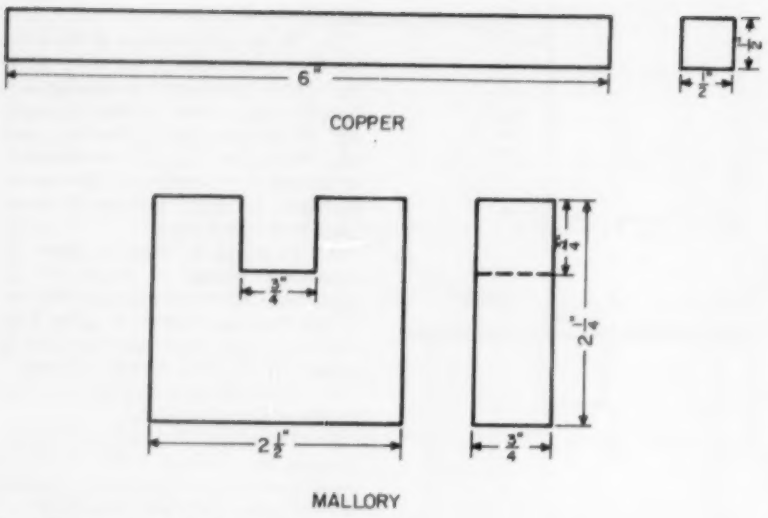


Fig. 10 Backing bar geometry

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References

1. Nippes, E. F., and Domina, F. H., "Series Spot Welding of 0.036-In. Auto Body Steel," THE WELDING JOURNAL, 19 (10), Research Suppl., 535-s to 543-s (1954).
2. Millar, N. P., and Kavaliauska, A. A., "An Ampere-Squared-Second Indicator for Resistance Welding," *Elec. Engr.*, 69 (4), 362 (1950).
3. *Resistance Welding Manual*, Resistance Welding Manufacturers Assn. (1948).
4. Hipperson, A. J., "A Mains Operated Valve Voltmeter for Measurement of Secondary Current in Resistance Welding Machines," Welding Research (British Welding Research Assn.), *Trans. Welding Inst.*, June 1948, April 1948.
5. McMaster, R. C., and Begovitch, N. A., "Instrumentation of the Spot Welder and Investigation of the Spot Welding of 0.091-In.–0.091-In. 248-T Alclad Sheet," THE WELDING JOURNAL, 24 (10), Research Suppl., 531-s to 556-s (1945).
6. McMaster, R. C., and Begovitch, N. A., "Spot Welding of Heavier Gages of Aluminum Alloy. Part II, New Portable Instruments for Rapid Measurement of Current and Tip Force in Spot-Welding Machines," *Ibid.*, 24 (12), Research Suppl., 644-s to 652-s (1945).
7. Richter, W., "An Instrument for the Measurement of Large Alternating Currents," *AIEE Trans.*, 63, 38–40 (January 1944).
8. Welding and Electrical Development Department, "A New Instrument for Measuring Secondary Welding Current to Promote Better and More Uniform Resistance Welds," Fisher Body Division, General Motors Corp., Process Development Plant, Detroit, Mich., Rept. No. H-180 (May 1952).

RESEARCH NEWS

(*Continued from page 607-s*)

50 by 130 ft, houses the 5,000,000-lb testing machine and the Amsler repeated load equipment. It is serviced by a 20-ton crane 65 ft overhead.

The original building, which was built in 1909, has been completely renovated. It has a test bay measuring 50 by 110 ft served by a 10-ton crane 35 feet overhead. This bay houses an 800,000-lb universal machine, and a 2,000,000 in.-lb torsion machine. A variety of smaller tension, compression, torsion, impact and hardness testing machines as well as a complete variety of strain and deformation measuring instruments are available.

Special laboratories for instruction, research and testing in concrete, hydraulics, materials testing, soils mechanics, sanitary engineering and structural models are provided.

Summer Course in Structural Steel Design at Lehigh

Nearly 300 engineering educators and consulting engineers from 39 states, Canada, Sweden and Puerto Rico, learned during the week of Sept. 12, 1955, the results of a nine-year research program on plastic design in structural steel.

The educators attended a summer session at Lehigh University's Fritz Engineering Laboratory, Bethlehem, Pa. The session began September 7th and ran through September 15th.

Sponsored jointly by the American Institute of Steel Construction and Lehigh University, the course demonstrated that plastic design is a faster and more economic method of designing steel structures than methods used heretofore.

The nine-year research program at the University has been sponsored, in addition to the AISC, by the Navy Department, the Welding Research Council and the American Iron and Steel Institute.

The new design concept calls upon the "ultimate" strength of structural steel as revealed by analysis of its plastic rather than elastic behavior under load. Substantial savings in cost through the more economic use of steel and savings in the design office are expected to be made possible by the more simple plastic methods. At the same time, building frames will be more logically designed for greater over-all strength.

The course reviewed the behavior of steel structures loaded beyond the elastic limit, and presented the fundamental concepts of plastic analysis. Demonstrations included actual tests of structures to illustrate the principles.

The objectives of the course are to provide educators with basic information so that they may introduce these concepts into their teaching at the earliest possible time; to provide information to design engineers in industry and government; to help create a receptive attitude on the part of designers, looking toward the time when building codes will be revised to permit application of plastic design.

All lectures were given by members of the staff of the Fritz Engineering Laboratory who have participated extensively in this research.

18 Smooth, Uniform Braze Welds in 8 minutes Add Economy to Quality in Peabody Classroom Chairs

Braze welded frame of PTAR Tablet Armchair

Braze welded frames for Peabody school furniture—combination of chair and open-front table.

Anaconda-997 Low-Fuming Bronze Rods Make Well-Shaped Braze Welds, Essential for Eye Appeal and Extra Strength, Says Leading School Furniture Manufacturer—and Lower Production Costs too.

The Peabody Seating Company, Inc., North Manchester, Ind., has been making quality school furniture since 1902. Well-shaped braze welds, they say, are essential to maintain this quality. And they have found that Anaconda-997 Low-Fuming Bronze Rods make this kind of joint, not only adding eye appeal but providing the extra strength needed in school furniture.

By depositing smooth-flowing and low-fuming weld metal, these rods promote faster, more uniform work and thereby reduce production costs. The 18 braze welds pictured are made in 8 minutes—an average of about ½ minute per joint.

Anaconda-997 Low-Fuming Bronze is a superior welding rod used to join gray and malleable cast iron, steel and copper alloys by the oxyacetylene process. It is also used for repair welding, and to deposit bearing surfaces on steel and iron. You can get other Anaconda Copper Alloy Welding Rods for many different production and repair purposes. They are sold by distributors of welding equipment everywhere. Anaconda distributors are also a good source of practical advice on welding problems. Purity Cylinder Gases, Grand Rapids, Mich., and Warsaw, Ind., furnish Peabody with Anaconda-997 Rods. For additional information write for Publication B-13. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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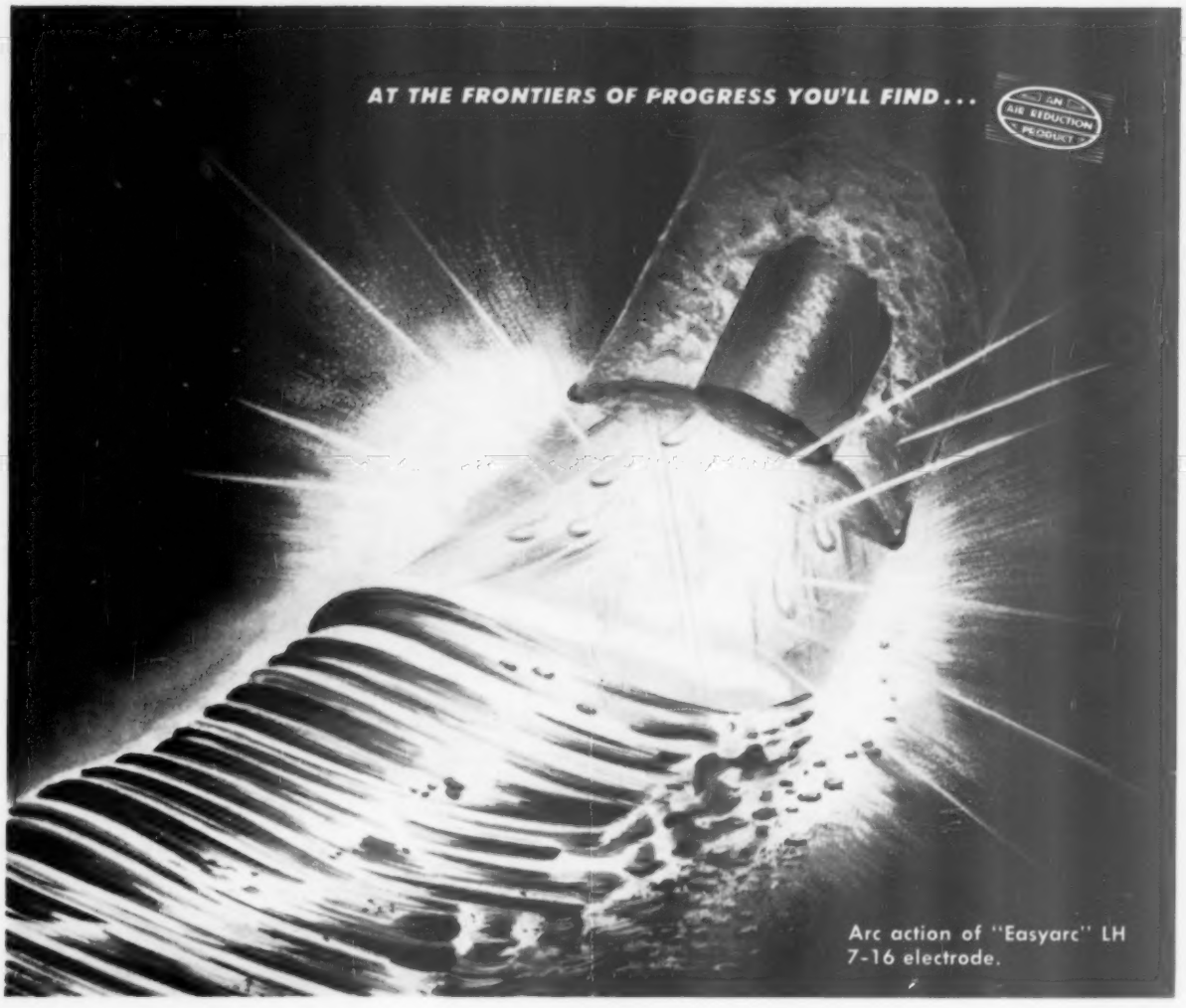
WELDING RODS



New "Easyarc" LH 7-16 deposits 60% more metal!

In comparative tests the new EASYARC LH 7-16 electrode deposited 6.58 pounds of metal per hour! This is actually 61.3% more metal than conventional low hydrogen electrodes of the same diameter.

Here's how the new EASYARC LH 7-16 does it:

(1) The concave end of the electrode concentrates the arc energy.

(2) Powdered iron coating melts and becomes an integral part of the weld.

(3) The extra-heavy coating helps control arc action and allows higher currents to be used in complete safety.

In addition to speed, the new EASYARC LH 7-16 produces outstanding results with hard-to-weld steels where highest quality is essential. Welds prove to have superior stretch and toughness characteristics. There's no underbead cracking. It's safe, too! The thick powdered metal coating is designed to eliminate the possibility of accidental arcing.

Let the new EASYARC LH 7-16 prove itself. Send for a *free* sample electrode today. Contact your nearest Airco office, Authorized Airco Dealer or write to Airco at the address below.

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